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SCIENCE IN A SOCIAL CONTEXT

BY

© ROBERT JOHN RITTER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Supervisor

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ABSTRACT

This study attempts to reveal the manner in which students perceive science and scientists, while studying science related social issues. By placing the context of science within a social setting, where controversial issues cannot be solved by scientific methods of problem solving, students were asked to explain how they have come to understand the nature of science.

Biology 20 students were presented with two issues during the course of their program. The ethical and moral questions that arose during research on age inhibiting drugs provided the framework for the first interactive debate, while the second focused upon the ethical and social consequences of recombinant DNA.

An examination of early educational research indicated that students express a limited and often erroneous image of the scientist and the nature of science itself. The most important question of my research addressed the manner in which students view the nature of science when science is presented within a social setting. Students' perceptions about scientists and the nature of science were extricably linked to the issues of age inhibiting drugs and recombinant DNA. Therefore, unlike most of the research on this topic I did not assume that the nature of science is able to be generalized. It is my belief that a proper interpretation of a student's perceptions of science must not only consider the

influences that each society places upon the research, but also the impact or at least the potential impact that the research will have upon society.

An examination of current research trends in science education indicates that quantitative studies, based on tight statistical analysis, still dominate research in this area, however qualitative studies, which attempt to describe and interpret educational settings "in situ" are providing an additional dimension. By first examining many of the quantitative test and critiquing them I discovered that the questions that I was most interested in asking were best approached from within a qualitative format.

Interview questions were constructed on the basis of each of the interactive debates. Interviews were taped and then transcribed. A validation followed each of the interviews and was also taped. The student responses from the two interviews and the subsequent validations were reorganized into a thematic approach for final interpretations and conclusions.

I found that students expressed a less naive perception about science and scientists, than was reported by earlier researchers. I also found that a student's rationale for expressing a particular viewpoint was consistent with their world view which is rooted within a philosophy.

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CHAPTER 1

INTRODUCTION TO THE STUDY

INTRODUCTION

RATIONALE FOR THE STUDY

DELIMITATIONS

ASSUMPTIONS

LIMITATIONS

CHAPTER 1

INTRODUCTION

On Friday, September 9th, 1983, the Edmonton Journal began running a series of articles that seriously questioned the quality of Edmonton drinking water. Drawing from information collected by Jim Bell, the newspaper reported that organisms such as Salmonella and Giardia, which causes beaver fever, are present in the North Saskatchewan River and are capable of being transmitted to humans (Struzik, 1983). The article goes on to suggest new drug-resistant organisms pose a potential threat in that high doses of antibiotics will not necessarily destroy these deleterious microbes.

In a subsequent article the Edmonton Journal presented an alternate perspective which indicated that the quality of the drinking water in Edmonton is the best in Canada (Chalmers, 1983). The article explains that most of the recorded violations of tested drinking water were for levels set for color, taste, odor or hardness; factors germaine to the aesthetic quality rather than related to health concerns.

When these apparent anomalies were presented to my Biology 20 class, the consensus of opinion suggested that either one side of the argument or other had fabricated its data to serve its own purpose, and that objective science was capable of disclosing a true answer. Although it became readily apparent that the students acknowledged the potential of scientists to select data or misrepresent the data, all of the students looked to what they considered objective science for the truth.

Therefore, according to the students, if the problem is indeed a science problem it must have a definite answer.

The perception of science as a time-tested methodology for problem solving was presented by the students in my class at the beginning of the year. Science for these students was the pathway to truth should it remain objective and unbiased. By looking for a methodology, unencumbered by political, economic, or social pressures for the answer to this question, students attempted to separate the activity of science from the scientist who lives amid these influences and pressure. For these students science becomes a disembodied activity, regulated by controlled variables and rigidly constructed rules; rather than a social activity performed by men and women with political bias and cultural influences.

Robert Nadeau and Jacques Desautels reflect upon the perception of a scientist operating as an objective being in the following quotation.

> "The research scientist is envisaged as a pure spirit, a being on a higher plane, capable of remaining detached from the surrounding world and exercising powers of thought with complete objectivity, untroubled by the concerns that usually beset lesser mortals and distort their perception of things. From this point of view, to be a scientist is to be untouched by material ambition, by the quest for prestige and glory, by the desire for professional advancement, by the lure of money" (1984, p. 38).

Science, at least in its purest form becomes not only a proven problem solving method, but linked with objective knowledge, it becomes the pathway to truth. However when I

indicated how the two groups of scientists had come to divergent conclusions the students began to re-examine many of their assumptions.

It was explained that both groups used the same technical methods for assessing water quality, but that each group had selected different sampling sites. By explaining the rationale set forth by each group for choosing their sample sites, students began to acknowledge the subjective nature of the scientific endeavor.

The questions that remain for research in this thesis are:

1. What assumptions do students hold about the manner in which scientific knowledge is constructed?
2. How do they formulate their opinions about the nature of science?
3. How do students come to understand the interactions of science and society, when studying science within a social context?
4. How does the study of science-related social issues influence the manner in which students perceive science and scientists?

Rationale for the Study

Much of the criticism directed toward traditional science programs centers upon an apparent preoccupation with factual knowledge and its ever increasing detail (Yager, 1982). One of the often mentioned problems associated with this fact oriented approach to curriculum is the distorted view of science that it

presents to students (Mead and Metraux 1957, MacKay 1971, McInerney 1982, Hurd 1969). Yet in spite of the apparent inadequacies of this fact oriented, and what Jacknicke (1984) has referred to as a "technical approach to curriculum development, implementation and evaluation" its dominance continues.

One of the solutions to the perceived crisis suggest that science should be presented in a social context, which stresses the humanistic natures of the scientific pursuit (Aikenhead 1980, Yager 1982, Bybee 1982, Hickman 1982a), and dispels the myth that empirical science is unbiased (Medawar 1969). Joseph McInerney (1982) indicates that:

> "We in science education must do a better job of teaching the public that science is a dynamic process, that data are mutable, that experts are fallible and that science and technology indeed have their limits." (page 103)

The focal point for this study is centered upon the ways in which students perceive science and scientists while encountering science related social issues. Do they feel that science presents unmitigiated and static truths; or can scientific knowledge be used to support divergent positions in response to a specific issue? Can values influence scientific interpretations and the creation of its knowledge?

These are but a few of the questions which stand in the forefront of the research. It should be pointed out at this time that the nature of science as perceived by students was explored from within the context of science related social

issues and therefore the discussion about science was inextricably linked to the specific issue being investigated.

Delimitations

The study was carried out in a single school setting that would likely be categorized as central urban, and best described as multi-ethnic. The eight participants involved in the interviews were volunteers, and therefore are not necessarily representative of all students or even a majority of opinions. Although an attempt was consciously made to select students who expressed divergent points of view, no attempt was made to identify students who expressed divergent attitudes toward science; and, therefore, no claim of a random sample is expressed.

All participants in the study were exposed to the same teacher and the same social issues. It should also be noted that the same individual was responsible for both the orginizational framework in which the discussions took place and the subsequent interviews with the volunteer participants.

Assumptions

The study as outlined is based on various assumptions.

1. Perceptions about social issues, by high school biology students, can be disclosed through interviewing techniques;
2. Student perceptions about the nature of science can be expressed and interpreted within a qualitative format;

3. Student perceptions about the nature of science are affected by studying science in a social context;
4. Student opinions are idiosyncratically related to the science related social issue and their value system;
5. The presentation of a science related social issue can be accomplished without cueing a predetermined response;
6. The same person can act as both teacher and researcher; and,
7. The class discussion will be the primary framework in which a student views the scientific endeavor, instead of the interview itself.

The study was premised upon the idea that science is a multifaceted endeavor that cannot be reduced to a simple all-encompassing explanation or viewpoint. Therefore, no attempt was made to provide students with a "correct" way of seeing science, nor did I evaluate divergent perspectives on the basis of a pre-determined definition of science.

Limitations

The following limitations have been identified:

1. That the views expressed by the students are affiliated with the context of the social issue in which that perspective was expressed, and therefore may not be transferable to all social issues.
2. The students perceptions of the nature of science is

is also affected by personal knowledge, and value systems. Therefore the same conclusions cannot be ascribed to all or even a majority of students.

3. The student's perception of the nature of science is also affected by their attitude toward science and the manner in which the science related social issues are presented and dealt with in a classroom setting. Thus the teacher's instructional methodology and relationships to the student also affect the interviews and opinions.

CHAPTER 2

REVIEW OF LITERATURE

OVERVIEW

SCIENCE VERSUS SCIENTISM IN HIGH SCHOOL SCIENCE CLASSROOMS

THE NATURE OF SCIENCE

LIMITATIONS OF SCIENTIFIC REASONING

A NEED FOR SOCIAL ISSUES IN SCIENCE CLASSROOMS

CHAPTER 2

LITERATURE REVIEW

OVERVIEW

In the review of the literature I begin by presenting some of the early research which has indicated some of the commonly held misconceptions about the nature of science, by students. Within this section I outline these misconceptions, and identify them with a misapprehension of science referred to as scientism. Upon differentiating scientism from science, I go on to indicate some of the inherent difficulties in providing an all encompassing definition for the nature of science. Accepting many of the points presented by science philosophers like Popper, Kuhn, Lakatos and Feyerabend I also indicate how they differ. My interpretation of the nature of science is left with an examination of science as a social activity, rather than a philosophical definition of science.

Next I examine the limitations of scientific reasoning as a problem solver. Again in this section my perceptions of science can be best illustrated by explaining both what it can and can't do. In the last section of the literature review I examine the need for social issues in science classrooms. It is my contention that when science is presented within a social context students develop a more realistic perception about the nature of science.

Science Versus Scientism in High School Science Classrooms

The image of the scientist among high school students (Mead and Metraux, 1957) and college students (Beardslee and O'Dowd, 1961) has provided a basis to understanding why students hold a limited view of science. Mead and Metraux (1957) have summarized the image of the scientist by analyzing open-ended essays at more than 120 schools throughout the United States. They found that students described scientists as cold, unemotional men, capable of detaching themselves from their environment and acting objectively as they set up their experiments and collect their data. Those students who described the positive attributes of the scientist described him as (Mead and Metraux, 1957):

> "... Very intelligent man - a genius or almost a genius... He is careful, patient, devoted, courageous, openminded... He records his experiments carefully, does not jump to conclusions, and stands up for his ideas even when he is attacked. He works for long hours in the laboratory sometimes day and night, going without food and sleep. He is prepared to work for years without getting results and face the possibility of failure without discouragement; he will try again... He is a dedicated man who works not for money or fame or self-glory but for the benefit of mankind..."(page 387).

While those who described the scientist negatively portrayed a similar image as they described the scientist as (Mead and Metraux, 1957):

> "...a brain; he is so involved in his work that he doesn't know what is going on in the world. He has no other interests and neglects his body for his mind. He can only talk, eat, breathe, and sleep

> science. He neglects his family - pays no attention to his wife, never plays with his children." (page 387)

These same misconceptions concerning scientists and the nature of the scientific enterprise follow most students through high school and into university (Beardslee and O'Dowd, 1961, Mitias, 1970). The stereotypic perception of the scientist in the study by Beardslee and O'Dowd (1961) rates him lowest among individuals in the 15 high-level occupations in sociability. Thus the demands of objectivity at least according to the college students in Beardslee's and O'Dowd's study, necessitate a withdrawal from the external influences that may compromise his neutrality, and thereby bias his research.

Thus the scientific process requires that a scientist detaches himself or herself from the influences of society to protect the objectivity that underlies his or her research. For science is best performed in a vacuum, free from social, economic, political or religious encumbrances that might bias this value free endeavour. Beardslee and O'Dowd, (1961), found that not only do scientist transcend many human weaknesses, but their perceived superior intelligence synergistically provides open-mindedness and a sense of morality. Apparently the students found some solace in knowing that a man or woman unconcerned with the trivalities of money and material rewards is beyond reproach. A moral person to be revered and trusted. Thus the crumpled suit and uncombed hair have become a stereotypic image that reinforces the notions of detachment and

incorruptability, and helps allay our fears.

In the study by Beardslee and O'Dowd (1961) "the image is the same for freshmen as for seniors." (page 1000) Thus a dominant and yet distorted or exaggerated view of the scientist obscures the nature of the scientific endeavor as a humanistic activity, inextricably linked with social, economic and religious influences and knowledges. Paul de Hart Hurd (1975) suggests that the youth of today struggles to find sources of knowledge that are "meaningful for generating new insights into the relation of human beings with the realities of nature" (page 27), and that these insights are generated through studying science within a social context.

Much of the research into the nature of science that recorded student preceptions about science and scientists began in the late 1950's and early 1960's, but it was somewhat abandoned during the 1970's. Although a great number of measurement devices originated in the 1970's, they were not employed to identify student perceptions about the interrelationships of science and society. The focus of the research in that era centered upon process skill development, and an understanding of the nature of science moved from a philosophical study concerning itself with student perceptions about scientists and the manner in which scientific knowledge was organized by society to the measurement of a student's comprehension of specific process skills. My review of the literature reflects this change in emphasis in that many of the perceptions about science and scientists end in the 1970's, but

the review of measurement devices provides a great quantity of information to the present. A revival of science and society concerns is reflected again in the 1980's by the works of Hickman (1984a, 1984b), Aikenhead (1980) and many recent researchers.

The perceptions by students in the aforementioned studies describe scientism rather than modern science. Scientism tends to be based on the presupposition that there are real isolated entities, standing apart from human perceiving and conceiving, which are present, and waiting to be revealed, like a missing link to a puzzle or an ancient artifact covered by the sands of time (Eastman, 1969). Scientism proposes a single truth, immutable, unchanging and independent of language and culture. This truth exists in an absolute form; not interpreted or mediated by man but rather unveiled by the scientific enterprise.

Thus scientism is ontologically rooted within the confines of naive realism, which proposes that material objects or forms exist independently of us. The paradigmatic construct of "realism" marks a sharp contrast with "idealism" or "phenomenalism" which take objects to be wholly constructed out of appearances or ideas (Bullock and Stallybrass, 1977). George Eastman explains (1969):

> "In scientism the ultimate pre-existing reality that is to be uncovered is material, consisting of individual entities to be unearthed, polished and placed on display as tokens of triumph of man over ignorance. Scientism holds that 'scientific advancement' consists of the accummulation over time, of these

> unearthed material truths (ie. laws, principles, objects, events); that the number of these 'truths' is finite..." (page 20).

Scientism is the dominant conception of science perpetuated by scientist and educators (Eastman 1969, Aikenhead 1973, Cawthron and Rowell 1978, Mitias 1970), who assume that science "designates the truth and ultimate way to solve the problems of nature and man". (Eastman, page 20)

The potential dangers of the pursuit of scientism, under the guise of science, can readily be evidenced by students turning to pseudoscience. Genetic determinists are but one example of pseudoscientist who have employed the guise of objective science, value free and uncompromised by social or political taint, to perpetuate racist propaganda. Louis Agassiz (1850), in providing a rationale for assigning whites a superordinate phylogeny to blacks wrote:

> "Naturalists have a right to consider the questions growing out of men's physical relations as merely scientific questions, and to investigate them without reference to either politics or religion." (page 111)

Stephen Gould in his The Mismeasure of Man identifies the paradigmatic framework provided by scientism, in the name of science, as legitimizing our misconception of intelligence. Gould (1981) refers to the alactrious theory as a "reification", in that abstract concepts, such as intelligence, are converted into physical entities, in this case the brain. Thus the word "intelligence" which conveys complex and multifacted sets of human capabilities is described and

evaluated as a unitary and separate thing. Gould explains (1981):

> "Once intelligence becomes an entity, standard procedures of science virtually dictate that a location and physical substrate be sought for it. Since the brain is the seat of mentality, intelligence must reside there." (page 24)

A natural extension of this reification set the stage for crainometry, as a means of assessing intelligence during the nineteenth century, followed by intelligence testing via I.Q. scales during the twentieth century. Steeped in the tradition of the platonic realists, we look to the mind as a separate entity to describe a phenomena that embodies the total human.

Public doubts about science (Handler, 1980) may well stem from the misconstrued image of science presented to the public (Marshall 1979, Aikenhead 1980). George Eastman (1969) describes the misrepresentation of science as one of the most pressing dangers facing educators. Eastman wrote:

> "Those who accept scientism for science are especially likely to fall victim to the grossest dehumanizing and depersonalizing aspects of our postcivilization. They are likely to have a blind faith in the Great God Science (ie. scientism) and so to uncritically and irrationally absorb its claims and its products and eventually to become its docile pawns." (page 22)

The Nature of Science

Many philosophers of science, notably Popper, Kuhn, Lakatos and Feyerabend, have attempted to re-define the nature of science, but there is little agreement between them (Hodson, 1982). A traditional definition of science, as explained by

Francis Bacon and John Stuart Mill, draws upon inductive and deductive reasoning (Hempel, 1966). Induction was described by Mill (Passmore, 1966) as a form of logic that leads one to generalizations or inferences from a single or reoccuring phenomenon, (page 17), while deduction provides a basis for prediction. However the aforementioned contemporary philosophers have rejected the traditional account of the scientific process (Hodson, 1982). Firstly, they indicate that unbiased observation does not exist. Secondly they reject the dual presuppositions that lie at the foundation of the inductivist explanation:

1. Science originates with observation.
2. Observation provides the origins, from which our knowledge is derived.

For Karl Popper (1963) science proceeds by "conjecture" and "refutation" towards a complete theory or explanation. Lakatos (1978) rejects the Popperian explanation and suggests that a "positive heuristic" guides science. Progress for Lakatos is commensurate with the ability of the new theory to lead to the discovery of a new fact. So, for Lakatos, science progresses not by refutation, as Popper suggested, but by confirmation.

Thomas Kuhn (1962) proposed a perspective that denies the notion of science progressing by degrees closer to a substantiated or existent truth. Kuhn suggests that there can be no purely objective criterion for accepting one paradigm over another. Change is explained as a "gestalt switch" or a

"religious conversion", not in terms of the falsification of traditional theories or the heuristic capacities of the newer theory. One theory is not superior to another, it merely provides divergent perspective of the world and operates within a different orientation or set of rules - paradigm. It is this relativistic expression of truth that initiates discourse between Kuhn and Popper (Hodson, 1982). Feyerabend (1975) also exposes the relativistic nature of scientific facts and knowledge and warns society about the influences of the scientific paradigm; yet, Feyerabend does not accept many of Kuhn's explanations.

The tendency to provide detailed and explicit definitions is embedded in the origin of Western philosophy. Hubert Dreyfus (1979) explains that the goal of the philosophical tradition, which he traces back to the ancient Greeks, is to "eliminate uncertainity: moral, intellectual and practical". (page 68) The demand that knowledge be expressed by a set of universally applicable rules is present in the writings of Plato. Socrates demanded of Euthyphro a set of rules that would provide explicit guidelines for assessing morality. Plato generalized this demand for certainty into an epistimological requirement. According to Plato, all knowledge must be expressed by explicit definitions (Dreyfus, 1979, page 68).

Formulating a definition that encompasses the nature of science is seductive, but it also opens the door to a maze that ultimately traps the author within the limitations of his own

definition. For the scientific endeavor is not a generalizable activity to be extracted and then analysed apart from the knower via all encompassinng definition. Michael Polanyi (1973) refuted the concept of a detached scientific knowledge. And MacKay (1971) suggests that the knowledge is dependent upon the context in which it was acquired.

Science is best described as a humanistic activity (Bronowski 1977, Gould 1981). To extend the definition would ultimately lead into the maze. For the definition of the term "science" becomes idosyncratically linked to activity itself. Goldstein and Goldstein (1978) distinguishes between the type of science that employs numerically exact calculations such as astronomy and psychology or sociology, which don't and are explained as imprecise. (page 5) The statement is proposed on the basis that generalizable laws used in astronomy can be supported by mathematics and that predictions are accurately verified by empirical evidence, while the predictions made by sociologists or psychologists rarely display the same statistical certainty. However, those authors point out that if the term "science" is defined within the boundaries of controlled experiments; astronomy, evolutionary biology and much of geology would have to be eliminated as true sciences. We cannot alter the path of the earth to see how such a change would affect the length of our year; nor can we re-introduce the dinosaur to determine extinction. The experiments that are performed under controlled laboratory experiment are more easily associated with aspects of psychology, and yet any

definition that employs the "paradigmatic" framework of controlled experiments in defining psychology eliminates much of what psychology is, let alone the other disciplines of science. Therefore, a definition of science that focuses upon the precision of predictions would provide a radically different perspective than a definition that was formulated around the type of science prevalent in a controlled laboratory setting. Thomas Kuhn (1962) pointed out a similar dichotomy between what he referred to as "normal science" and "revolutionary science".

Jacknicke (1983) has indicated that the technical approach to science curriculum development has presented a narrow view of science and has provided students with a misrepresentation of what science really is. Jacknicke's hypothesis is congruent with Ihde's (1979) premise that the technological paradigm amplifies one aspect of the world, in this case one specific notion of science, while reducing others. An often criticized aspect of school science has been the predominance of the puzzle-solving or logic welding (Munby 1982) characteristic of "normal science" and the exclusion of "revolutionary science" (Kuhn 1962), which tends to foster a dialectic of opposing viewpoints and value structures. As a result, science is perceived as static, immutable and factual. Its knowledge becomes easily affiliated with an absolute truth, while the myth of objectivity tends to isolate the knowledge from the knower.

By viewing science as a humanistic activity, we can focus

our attention upon the doer of the activity rather than the product of the activity. This orientation towards the scientist, within a sociological setting, would provide a potential avenue for a phenomenological approach to the presentation of science. Goldstein and Goldstein support this humanistic perspective by the following statement:

> "Science is an activity of creative and imaginative human beings, not of computers and other machines. The creativity and imagination must be controlled by discipline and self-criticism, but that is equally true of other kinds of creative activity such as the writing of poetry. And because it is a creative and imaginative activity, there are satisfactions in engaging in it no different from those felt by others in the same way that poems, pictures, and symphonies are" (1978, page 4).

Science moves by hunch, vision and intuition. (Gould 1981). The truth that it produces is affiliated with the social context in which it was derived and, according to many philosophers, should not be misconstrued as absolute truth (Kuhn 1962, Feyerabend 1975). Facts are not pure, immutable and independent of the culture in which they were developed. Karl Popper in "Science: Conjecture and Refutations", explains that observation does not preceed theory, but occurs within a particular orientation that delimits and selects what is seen (1963, page 46). The knowledge constructed within the discipline of science is a specific way of viewing the world (Munby, 1982), and is only one of a number of ways of knowing (Hurd, 1975).

Scientific knowledge is created within a particular

paradigmatic structure and, like theology, logic of aesthetics provides its own truths that may not be consistent with those produced by other disciplines and only retains veracity when applied to those questions answerable by this particular way of thinking. Glen Aikenhead (1980) warns against the indiscriminate use of science to solve all of the problems in our society.

> "Science is limited by its aim. Science cannot be stretched beyond its function of satisfying natural phenomena. Beyond that function, one would look to another sector of society..." (page 52).

Science then is best viewed as a multifarious activity, as diverse in description as the scientists who perform the activity, and the culture that interprets its knowledge.

Limitations of Scientific Reasoning

The compatability of logic with the commonly held view of science not only legitimized science but elevates it as the ultimate authority in our technological society (Bronowski, 1977). Science, because it employs a particular kind of logic has been identified with the thinking process of logic to the exclusion of other ways of thinking. Thus, the acceptance of a scientific fact or theory is premised upon the notion that all decisions in science are based upon logic (Bronowski, 1977). However many decisions in science clearly transcend the boundaries of inductive and deductive logic.

A cogent example was provided by Glen Aikenhead (1980) in response to the abortion debate. Aikenhead indicated that,

when asked for comment, a federal cabinet minister said "that he would wait until science defined when an embryo becomes human before he would take a stand on the abortion issue" (page 11). The cabinet minister, by identifying the abortion issue as a science-related problem, believed that the scientific community could provide him with an answer.

What happens when the question "when does life begin?" is approached from a scientific paradigm, and excludes other forms of thinking?

Aikenhead (1980) indicates that a major limitation of science is the principle aim of the scientific activity. He states:

> "The goals of individual scientists vary from prestige, to helping humanity, to the pursuit of 'truth'. However, the collective consciousness of the scientific community recognizes the satisfaction of curiosity as it's principle goal. Science is limited by this aim. Science cannot be stretched beyond its function, of satisfying curiosity about natural phenomena. Beyond that function, and beyond natural phenomena, one would look to another sector of society, such as technology, religion or perhaps the pseudo-sciences" (page 52).

Therefore when the aforementioned cabinet minister, looks to science for an unequivocable answer, he exposes a basic misunderstanding about what science can and can't do.

Philip Handler (1980) indicates that the public "has somewhat lost confidence in the scientific endeavor" (page 1093). It is not that the scientist has lost esteem but, according to Handler, the public is now less convinced that science is capable of producing a better society. This lost

confidence in science and technology (Handler 1980) can be related to the public's distorted image of science (Marshall, 1979) and the tendency to indiscriminately apply the scientific paradigm to problems that far exceed its limits. It is this indiscriminate application of the scientific approach to all problems, be they purely scientific or not, that has led Apple (1975) to state that "scientific outlooks have become so ingrained in our consciousness that they have become values, not merely a way of gaining knowledge" (page 123). Problems that deal with science, technology, and society should not be approached from any single orientation in isolation (Hurd, 1975). Handler (1980) indicates that difficulties arise when scientists fail to recognize that their own ideological beliefs and values influence what might appear to be scientific debates.

An important limitation of science must be considered from the social context in which its knowledge is constructed. According to Berger and Luckmann (1967), knowledge is socially constructed and internalized as both an objective and subjective form of reality. Scientific knowledge itself must be viewed as a limited representation of reality rather than reality itself (Aikenhead, 1980). Aikenhead explains:

> "Models, classification schemes, equations and hypotheses, concepts and facts, all are useful representations of reality....They are not reality itself" (page 58).

Aikenhead (1980) goes on to state that his view of science challenges the dogmatic belief that science is objective

reality and absolute truth (page 58). By assuming that the scientific community could define when an embryo is human, the misguided cabinet minister looks to science as a problem solver. This popular misconception, the objectification of life itself, provides a cogent example of the manner in which science is misapprehended and its heuristic overestimated.

Paulo Friere (1970) similarly refutes the notion of understanding the world as objective reality. Friere explains:

> "For man, this process of orientation in the world can be understood neither as a purely subjective event, nor as an objective or mechanistic one, but only as an event in which subjectivity and objectivity are united". (page 6).

Somehow there has crept into science and science education the notion that the natural sciences are truly objective, while humanistic studies are subjective; that science stands outside of the nature of man (Glass, 1965). This misguided perception ignores the fact that all knowledge is socially constructed (Berger and Luckmann, 1967).

By describing science as a humanistic activity, an important limitation is revealed. Science is limited by the society in which its knowledge is constructed and "by the human characteristics of those creating and extending its knowledge, and therefore science is affected by human foibles such as fads, falsifying, dogmatism, nationalism..." (Aikenhead 1980, page 60). It is constrained by the evolutionary state of man, by the limitations of his senses and most importantly by the powers of human reason (Glass, 1965).

In conclusion, science must be viewed as a socially

constructed activity that provides one specific way of looking at an interpretation of the world. An orientation that seeks to explain natural phenomena by casual relationships. Karl Mannheim (1936) points out "that our conception of science is much narrower than the scope of present day knowledge, and that attainable and communicable knowledge by no means ends at the boundaries of established present day sciences" (page 165).

A Need for Social Issues in Science Classrooms

Science educators face the dual task of both preparing the professionals who will propose possible solutions to science created social problems and of educating the mass of citizens who will help decide how those solutions are translated into social and public policy (McInerney, 1982). To argue which is more important is to miss the point that science and social policies require informed participation by both groups. School science teaching has, therefore, a special responsibility to ensure that students understand both the potentials and limitations of the scientific endeavor (Aikenhead, 1980).

However, in spite of this apparent need, little evidence indicates that teachers are introducing controversial issues in the classroom (Hickman, 1982b), and students remain hesitant to take a science and society course when it is offered (Rosenthal, 1979). Less than 26% of the biology teachers in a United States survey indicated that more than 40 minutes a year per class was devoted to bioethical issues (Blaga and Cooney 1981). Paradoxially, a survey, conducted by NABT (National

Association of Biology Teachers) (Hickman, 1982a), indicated that 77% of those teachers surveyed believed that the study of science-related social issues were consistent with the objectives of their program. So why aren't science and society issues dealt with in science classrooms?

An explanation of the aforementioned paradox becomes somewhat illuminated when Hickman (1982a) reports that only 33% of the respondents indicated that preservice and inservice education adequately prepared them to deal with science/society issues in the classroom. Characteristically science educators have avoided value laden issues, suggesting that these topics are best dealt with in social studies, where terms like "values", "conflict", "issue" and "controversy" are more amenable (Hickman, 1982b).

It is this artificial separation of science from the value systems and the social context in which it has developed that has perpetuated the erroneous notion of a neutral objective science (Agin and Pella 1972). Paul de Hart Hurd (1975) explains that:

> "Science has a value dimension any time it induces conflict in our thinking, modifies the culture, or makes demands on society and this is most of the time. While science does not directly impose values, it creates conditions which demand the reinterpretation of old values or the formation of new ones". (page 28)

Programs that provide a value focus for high school science students (Rosenthal 1979, Ophulss 1980) claim not to teach a particular set of values, but provide students with an opportunity to reflect upon and clarify their own values, and

compare them with those of others. Social tolerance and mutual respect in a pluralist society require a recognition of divergent world views and an appreciation for the ways in which facts are socially constructed. Yet these courses tend to be neglected in favor of the more traditional content or information bound science programs (Hurd 1982, Glass 1965, McInerney 1982, Bybee 1982).

What is needed is a new orientation of biology (Hurd, 1982) that sees the concerns of humankind as central to instruction, while developing a world view that provides a consociation of Man in and with Nature (Freire 1974) rather than man outside of nature. Clearly science education must do a better job of teaching the public that science is a dynamic process, that data are mutable, that experts are fallible, and that science and technology indeed have limitations. The implications for educators are in providing the environment that fosters a healthy, realistic skepticism that promotes good decision-making, and active, responsible participation in the evolution of social and public policy questions that involve science and technology (Benne and Barnbaum, 1978).

Teaching science with a value focus provides students with a means for interpreting what they have learned within their own experience (Hurd, 1975). Hurd sees the goal of values clarifcation as developing a value sensitivity for studying the interactions of science, technology and society. Some of his specific objectives are germaine to the limitations of science:

1) to understand that valuing is a way of knowing.

2) to appreciate that there are aesthetic answers to human problems as well as scientific answers.

3) to go beyond the description of facts and to consider how they may best serve people, and to explicitly study the interaction of science and society (Hurd, 1975).

CHAPTER 3

SELECTION OF METHODOLOGY

OVERVIEW

DIFFICULTIES IN DETERMINING A STUDENT'S UNDERSTANDING ABOUT THE NATURE OF SCIENCE

A SURVEY OF INSTRUMENTS USED TO DETERMINE A STUDENT'S UNDERSTANDING ABOUT THE NATURE OF SCIENCE

A CRITIQUE OF TESTS THAT PURPORT TO MEASURE STUDENT UNDERSTANDING ABOUT SCIENTISTS AND THE NATURE OF SCIENCE

THE QUALITATIVE ALTERNATIVE

CHAPTER 3

OVERVIEW

In this chapter I will examine the problems encountered when attempting to determine a student's understanding about the nature of science. In the first part of the chapter I indicate how many experts interpret the nature of science based upon different criteria. A common focus for what should be investigated is not held by all researchers. Within this section of the thesis I survey some of the more commonly used quantitative instruments to demonstrate how each of these devices select different aspects of science.

The second section of this chapter presents a survey of the methodologies that have been used to determine a student's understanding about scientists and the nature of science. From this survey it is very apparent that quantitative methodologies far outnumber qualitative approaches. A critical evaluation of the quantitative methods used to explore a student's understanding of science follows. The critical evaluation is designed to show some of the problems which befall most measurement devices, but it also presents specific problems within measurement analysis. The critical assessment both uncovers those questions that quantitative surveys best address, and those questions that are best approached by qualitative research.

In the final section of this chapter I outline the type of

questions that I wish to investigate, and indicate why those questions are best approached from a qualitative format. The quantitative and qualitative approaches are compared, but not as a means for finding the best overall method. Their comparison is constructed in a manner which explains how they approach questions from divergent world views, and how these different metaphysical orientations can be complementary rather than opposing.

Difficulties in Determining a Student's Understanding of the Nature of Science

All too often a student's conceptual knowledge about science has been tested in order to determine an understanding about the nature of science. The presupposition being, that in order for a student to do science, or at least classroom science, the scientific attitudes and attributes must be employed. Thereby, the ability to do science becomes commensurate with the student's understanding of the scientific activity. Conant disagrees with this viewpoint when he says that "being well informed about science is not the same thing as understanding science, though the two propositions are not antithetical. What is needed are methods for imparting some knowledge of tactics and strategy of science to those who are not scientists" (1947, p. 12)

An understanding of science, in the view of most educators should extend beyond the organization of facts. Joseph Schwab indicated that, all too often, traditional presentations of

science have been concerned with scientific knowledge expressed as a "rhetoric of conclusions" (1964, p. 24). Leopold Klopfer voices a similar criticism in that he feels that "science is presented as a body of knowledge which is static and proven true" (1976, p. 564). Schwab explains that:

> "... we cannot avoid the realization that science is a process of contructing bodies of tentative knowledge, of discovering different ways of making data coherent and 'telling' about a given subject matter" (1964, p. 35)

This much criticized traditional approach to science education, has been affiliated with many erroneous notions that some students, teachers and scientists express about the nature of the scientific endeavor (Klopfer 1974, Hurd 1969, 1970, McInerney 1982, Yager 1982, Jacknicke 1983). A call for a reformulation of traditional goals in Canada (Page 1979, Aikenhead 1980) and in the United States (Hurd 1969, 1982a, Hickman 1982) with the expressed intention of incorporating and emphasizing the relationships between science and society has provided one alternate approach. Similarly Nay (1971) and others have indicated the advantages of a process-inquiry oriented approach to science "to enable students to understand science and scientists better..." (p.197).

For Nay (1971), a better understanding of the scientific endeavor is premised on providing students with the opportunity to imitate the activities of a scientist. Nay and Crocker (1970) indicate that an understanding of science must include a process dimension of science as it relates to inquiry and some recognition of the attitudes scientists exhibit while doing

their research. Billeh and Malik (1977) share this multidimensional view of science. For them, to understand science, "one needs to understand; its basic assumptions, characteristics of the scientific enterprise, processes through which knowledge is acquired and developed, and above all the ethics of science" (p. 559). Thus each of the authors use a different criterion for determining a student's understanding about the nature of science.

Aikenhead provides a list of instruments which purport to measure a student's knowledge about science and/or scientists. The list includes: "Test on Understanding Science", "Facts About Science Tests", "Nature of Science Scale", "Science Process Inventory", "Wisconsin Inventory of Science Processes" and "Test on The Social Aspects of Science" (1973, p. 541).

Aikenhead presents the following table as an approximate qualitative comparison among six instruments (1973, p. 545)

1	2	3	4	5
content	process	nature of science	science/ society	attitude
		TOUS		
			FAS	
		NOSS		
SPI				
WISP			TSAS	

From the chart it become apparent that a common definition for measuring a student's understanding about science and scientists is influenced by the author's emphasis on one or

more of the various aspects of science. Therefore, the selection of the appropriate measurement device is imperative for the answering of specific questions.

Aikenhead indicates a similar concern in that:

> "The instruments that purport to measure knowledge about science and scientists (the TOUS, SPI, TSAS, WISP, NOSS and FAS) seem to have limitations to their appropriate use. The tests generally fail in research design to the effect of different teacher characteristics and teaching strategies. Perhaps the instruments were inappropriate or the research design ill conceived. At the same time however, the instruments were useful in experiments that concerned the content of science lessons. Hence the instruments do seem to be able to serve as criteria for measuring student learning which is directly related to the content of the tests. The instruments consistently measured the degree to which learning about science and scientists had been made explicit in the science courses" (1973, p. 546).

Much of the criticism that has been levied on specific instruments by Gauld (1982) or Gauld and Haukins (1980) may arise from their own expectations of the instrument, that in many cases far exceed the developer's intent; or the indiscriminate application of the instrument to inappropriate research questions.

A Survey of Instruments Used to Determine a Student's Understanding About Scientists and the Nature of Science

Traditionally, attitude scales have been used to measure a student's understanding of the nature of science. A survey of 50 studies, focusing upon attitudes to science provided the

following data (Munby, 1980):

Format	Frequency
Lickert	32
True/False	5
Thurstone	3
Guttman	2
Structured Interview	2
Multiple-Choice	1
Projective	1
Q-Sort	1
More Than One Format	3
Total	50

The dominance of the Lickert scale becomes obvious from the chart above; however the effectiveness of such scales remain a contentious issue (Billeh and Malik 1977, Gardner 1975, Munby 1980, Kozlow and Nay 1976).

The survey response format, in contrast to the interview, has been widely employed and appears in many different formats from multiple-choice questions to Lickert scales. The advantage of the written survey technique is that it readily yields quantifiable information that can be graphed, charted and compared; however the written survey rarely allows a follow-up question, nor does it require that the subject of the research provide his or her rationale for choosing a particular answer.

A call for more qualitative research was expressed by Glen Aikenhead in the following statement:

> "Researchers wanting to assess the impact science instruction has on students need to use evaluation techniques that move beyond the educational research habits of testing students with standardized instruments, of analyzing curriculum materials, and of amassing questionaire responses. Other methods of inquiry more appropriate to the task exist; using qualitative data, and conducting ethnographic and philosophical analysis of classroom proceedings." (1980, p. 25).

A Critique of Tests That Purport to Measure Student Understanding About Scientists and the Nature of Science

Gardner (1975) provides a critical review of the commonly employed instruments designed to measure attitudes to science. He explains that there is a general lack of coherent theoretical construct in many scales, so that as many as three quite separate issues are often fused into a single scale. Thus items measuring attitudes toward science, and scientists; and an understanding of the "Scientific Method", are found within a scale that offers a single score which is difficult, if not impossible to interpret. Kozlow and Nay (1976) also provide a critical perspective and indicate that many of the scales are guilty of one of the following inadequacies: "the definitions of attitudes are too general; there is a tendency to lump together several dimensions of science under the caption of attitudes, ... the scales do not discriminate between the affective and cognitive components involved in attitude measurement; and the content of the scales often does not adequately represent classroom situations and experiences" (p. 148). Aikenhead (1973) indicates that the value of the

instrument is largely dependent upon the nature of the questions asked, and the type of courses or programs that they are to evaluate.

Gauld (1982) suggests that most of the tests present an erroneous image of the scientists. He indicates that the conception of the scientific attitude "which appears in the science education literature sees the scientist as one who makes decisions solely on the basis of empirical evidience and who at all times prevents his personal interests from intruding into these decisions" (Gauld 1982, p. 118). Gauld (1982) criticizes Klopfer (1976) for retaining many of the traditional stereotypic images of the scientist, although he does not specify which images are objectionable or stereotypic.

Aikenhead (1973) indicates that many scales emphasize opinion about science over knowledge; and he cites the "Allen Attitude Scale" as a cogent example. Nay and Crocker (1970) also identify the "Allen Attitude Scale" as being poorly constructed. They explain that items "which are not true reflections of science and scientists" (p. 66) are present, and the following examples are given:

> "Scientists are 'eggheads'...One cannot have a normal family life and be a scientist" (Allen, 1959).

Nay and Crocker (1970) also identify the test "On Measuring Attitudes Towards Science" as suffering from many of the same failures as Allen's test. Gardner (1975) similarly identifies a scale entitled "Attitudes to Science Course at Training College" (Shah, 1962), as a "disparate collection of

items, reflecting attitudes towards a wide variety of attitude objects" (p.12) which makes it impossible to derive any meaningful score or interpretations. Gardner provides the following examples:

> "I feel that practical work in science should be done in groups."
> "I feel that the science course at college is too easy" (1975, p. 12)

One of the most prominent tests employed to measure a students understanding about science and scientists is the "Test On Understanding Science", form W. The TOUS test was developed by Cooley and Klopfer as a research tool. It is a four-alternate, sixty item, multiple choice test, that is divided into the following three subscales:

Subscale I	Understanding about the scientific enterprise (18 items)
Subscale II	The scientist (18 items)
Subscale III	Methods and aims of science (24 items)

Yet despite its wide usage, and apparent acceptance, a great deal of criticism has emerged. Welch and Pella (1968) have suggested that Form W requires stronger validity evidence. Nay and Crocker (1970) indicate that readability of the instrument used to measure a student's understanding about science and scientists is of paramount importance, when considering the results provided by the test. Thereby a high correlation between reading ability and test scores may indicate that either good readers also understand the nature of science, or that those who choose the incorrect answer did so because of poor reading comprehension. One of the difficulties

with any written test is it's inability to differentiate between reading skills and concept comprehension. Wheeler (1968) has suggested that too many items embrace a negative viewpoint of science and indicates that the test requires more items to increase its comprehensiveness. He recommends that the three category subscale be changed to a two category division: (1) the social aspects of science and (2) the nature of the scientific inquiry. Aikenhead (1973) indicates that "some items" evoke a response of attitude. He perceives the test as concerning student appreciation for science and scientists, rather than an understanding about the nature of science.

> "Some of the items are answered according to a scientist 'good guy' image" (Aikenhead, 1973,p. 541).

Kozlow and Nay (1976) cite TOUS among other tests, as not discriminating between the cognitive and the affective components involved in attitude measurement. They also indicate that the content of the scales does not adequately represent classroom situations and experiences (p. 148).

TOUS also provides a hidden definition and philosophic orientation for the nature of science. Consider the following question:

> "15. Of the following, which is the best statement about scientific knowledge?
> A. Scientific knowledge is a systematic collection of facts.
> B. Data and ideas from the past contribute to todays scientific knowledge.
> C. Each generation starts anew to build up its own scientific knowledge ". (Cooley and Klopfer, 1961)

Should a student accept the relativist philosophy of science, as expressed by Thomas Kuhn (1962) and Paul Feyerabend (1975), alternate C might be the best choice. However should the student accept a Popperian view of science alternate B would be most appropriate. If alternate A is chosen the makers of the TOUS test might assume that the student has a limited understanding of the way in which scientific knowledge is constructed. However the student may have interpreted the term "scientific fact" to incorporate theories and unconfirmed hypotheses that are supported by empirical evidence. The student who views a fact in science from the perspective of a relativist philosopher like Kuhn, may accept it as fact because it is congruent with observation, and demonstrates heuristic capacities; but this fact is not equated with an absolute truth. Thus an argument could be constructed to justify the selection of alternate A. To argue which of the divergent philosophies of science is correct, is to lose sight of the point. The point being made is that divergent paradigms can lead to different answers, and that the TOUS test provides no opportunity for the justification of an answer. Is it not possible that a student who selects the "wrong" answer may have a better rationale for his choice than the student who selects the "correct" answer?

Another widely used test is the TUNS or Test on Understanding the Nature of Science. Billeh and Malik (1977) developed this four-alternate multiple choice test dealing with the nature of science. The test consists of two sub-types of

items. The first type measures students knowledge of the assumptions and processes of science. The second category of questions requires the individual to make judgements based on his understanding of the nature of science. One of the inadequacies that Billeh and Malik found with the TOUS test was that it did not "present situations which require the individual to make judgements on his understanding of the nature of science" (1977, p. 560). They feel that the strength of their test lies in its application to decision-making.

One of the most important aspects missing from the TUNS test, is the interrelationships between science, technology and society. A failure to consider the history of science, and the evolution of scientific knowledge from within a cultural setting seriously limits the usage of the TUNS test. The point is best made by drawing upon an example from TUNS.

> "6. Statements of science are acceptable if they;
> a) are absolutely true
> b) demonstrate high probability of correctness
> c) are not likely to change in future
> d) do not contradict the value of the society". (1977, p. 570)

TUNS apparent neglect of historical perspective becomes clear in question number 6. I wonder if Galileo Gallei might not have chosen alternate D? If he did would the authors then conclude that he lacked an understanding about the nature of science?

By presenting a question out of context the test fails to acknowledge the possibility that the nature of science itself is evolving, and that the context from which scientific

knowledge is interpreted and accepted is indeed inextricably linked to the society that interprets that knowledge. Thus, espistemological questions must be presented within the context of a particular scientific endeavor and the social context in which it developed. From my perspective the interrelationships between science, technology and society present students with a cornerstone for understanding the nature of science.

Neither TOUS nor any other scale that I have surveyed provides a built in structure that might lead researchers to understand why the students choose a particular answer. The test operates under the presupposition that a "correct" answer is indeed a right answer from any perspective, and that divergent perspectives of the nature of science will not be discriminated against by the author's own philosophy. I believe that many of the questions in the tests are designed to demonstrate a congruency between the students' views of science, and those expressed by the authors, rather than an understanding about the nature of science.

Qualitative Alternative:

The qualitative design should not be regarded as a superior methodology to the more traditional and prevalent quantitative approaches. Like the quantitative approaches many inherent difficulties lie within the threads of qualitative approaches, however unlike the quantitative approaches, the qualitative framework remains a comparatively unexplored approach. Like any frontier, the qualitative paradigm presents

many untapped potentials, however it also contains many uncharted pitfalls. The true value of the qualitative approach therefore is not in replacing the previously established quantitative approach, but as a complementary form of research (Roberts, 1982). The potentials of the qualitative method lies in its ability to further uncover many of the findings laid forth by tests like TOUS, WISP and TUNS.

A bridge between the more traditional, statistical treatment of test results and qualitative follow-up studies is provided by Klopfer and McCann (1969). Their approach attempts to inject qualitative feedback into a formative evaluation study. Qualitative data from the TOUS (Test On Understanding Science) and SPI (Science Process Inventory) were reported by MacKay (1971) and Tamir (1972) respectively. For example MacKay studied the common misunderstandings among seventh to tenth grade students. He confirmed earlier studies by Beardslee and O'Dowd (1961), which indicated that students' perceptions of science seemed to remain unchanged, however he was unable to explain why their misconceptions do not change.

Quantitative and qualitative research in science education are based upon different sets of metaphysical presuppositions that originate from a different world view (Roberts, 1982). According to Douglas Roberts, quantitative research provides a formist/mechanist preoccuption, while qualitative research is contextualist/organicist (1982, p. 278).

Formism is concerned with the form of things and a comparison of these forms to the ideal forms (Roberts, 1982, p.

279). Thus a Platonic philosophical orientation is adopted by the researcher who holds this world view. According to Roberts:

> "All achievement studies and tests of all statistical significance incorporate formistic thinking" (1982, p. 279).

When correlations attempt to establish the link between causes, and the degree of similarity, and the strength of relationships researchers move from a formistic to mechanistic approach (Roberts, 1982). Both orientations require a basis of quantifiable data, and therefore both approaches lend themselves the quantitative research.

Contextualism is a perspective that focuses upon the context in which the event unfolds and is interpreted. "We have no adequate knowledge of an event, according to this world view until we know the context in which it occurs" (Roberts, 1982, p. 279). The contextual description of an event would best be accomplished by qualitative analysis. The organicist approach is described by Roberts (1982) as being very similar to the contextualist approach, however it emphasizes the wholeness.

According to Wilson (1977) qualitative research is established upon two presuppositions about human behavior which he refers to as: (a) the naturalistic-ecological hypothesis, and (b) the qualitative-phenomenological hypothesis. The naturalistic-ecological hypothesis is based on evaluating the event from within a classroom setting where it occurs rather than a reconstruction of the event by either models or

questionnaires. The qualitative-phenomenological approach assumes that the social scientist "cannot understand human behavior without understanding the framework within which the subject interprets their thoughts, feelings, and actions" (Wilson, 1977, p. 249). In contrast to quantitative approaches, prior limitations are not placed upon data, in that the subject first generates the event independent of pre-arranged categories.

> "The phenomenologist points out that the adoption of this particular framework for interpreting and coding behavior is arbitrary. Any number of meaning systems could be selected. In fact, the most inportant frameworks to understand might be those of the subjects rather than researchers" (Wilson, 1977, p. 250).

Severyn Bruyn (1966) supports this view in the following statement:

> "The traditional empiricist considers himself (as a scientist) to be the primary source of knowledge, and trusts his own senses and logic more than he would trust that of his subjects. The participant observer, on the other hand, considers the interpretations of his subjects to have first importance...By taking the role of his subjects he recreates in his own imagination and experience the thoughts and feelings which are in the minds of those he studies" (p. 12).

The quantitative approach does very little to uncover the reasons for the expression of a particular viewpoint. The well thought out rationale cannot be uncovered by only looking at the answer. While the quantitative methodology is best suited to measure the end products of thinking; the qualitative paradigm tends to focus upon the rationale that led toward

decision-making. A test on Science and Society constructed by Korth (1968) indicates that students view scientists as being politically neutral, but the test does not uncover the rationale that students use to support their conclusions. To argue which of the questions is most important would be ludicrous. A student's reasons for describing a scientist as being politically neutral cannot be uncovered until their perceptions have been established. The NOSS, TOUS, and TUNS tests may be well adapted as indicators, however they do not provide the entire picture. The inherent value of the qualitative approach lies not in supplanting the quantitative approach, but in providing another perspective to an understanding of student perceptions of science. It should be pointed out, that combinations of quantitative and qualitative research does not ensure a complete picture. The efficacy of the research findings can only be evaluated from the apparent framework contained in the design, and the interpretation of the results.

CHAPTER 4

PROCEDURE AND DESIGN FOR THE STUDY

OVERVIEW

INTRODUCTION OF THE SOCIAL ISSUES IN THE CLASSROOM

(I) PRESENTATION OF BACKGROUND INFORMATION
(II) INTRODUCTION OF TECHNOLOGICAL APPLICATIONS
(III) SOCIAL CONSEQUENCES
(IV) REFLECTION OF THE ISSUE
(V) BRAINSTORMING SESSION

THE USE OF ETHNOGRAPHIC METHODOLOGY DURING THE DEBATE

THE SELECTION OF STUDENT-INTERVIEW-PARTICIPANTS

THE INTERVIEW AS A RESEARCH TECHNIQUE

CHAPTER 4

OVERVIEW

In this chapter I outline two major components of the research. The first section deals with the manner in which the social issues were introduced within the classroom, while the second component deals with the manner in which the follow-up interviews and the validations were organized. Although it is not a customary format to include both of these components within the same chapter, it is particularly appropriate within the design of my study. A student's perception of science is investigated from within the context of the social issues studied, and therefore their perception of science becomes inextricably linked to the interactive debate. The debate not only provides a context in which future interview questions were constructed, but it also provides a format in which a student's values and feelings are commingled with their perceptions of scientific research. Hence, the organization of the debate becomes a major influence upon the manner in which students come to understand the nature of science.

Introduction of Social Issues in the Classroom

Two social issues were introduced to the students in two Biology 20 (grade 11) classes at a central high school in Edmonton, during the months of February and March of 1984. Units on "Age Inhibiting Drugs" and "Recombinant DNA" were

selected because they provided students with social issues that were readily integrated with the core units prescribed within the Alberta Education Biology Curriculum Guide (1984). The ethical and moral questions arising from the research and development of an aging drug were introduced within the context of cell division, while an investigation into the field of Recombinant DNA followed the core material on the structure of DNA and the mechanisms of protein synthesis.

The classes were both under my direction although the core unit on DNA and the subsequent social implications arising from this new form of biotechnology were introduced by a student teacher. A concerted effort was made on both the part of the student teacher and myself, not to become the focal point of the discussion, and thereby have our viewpoints influence the expression of opinions. Neither the student teacher nor I consciously presented our own personal perspectives, nor did we overtly give special recognition to students who expressed a particular point of view. It was considered that the role of the teacher and the student teacher would be in acting as an initiator of a scenario, and as a facilitator to background information, rather than as an orchestrator of classroom discussion.

A public forum-debate was selected as the best possible way to encourage involvement from the students within each of the classrooms. It should be noted that no attempt was made on my part to have students from different classes discuss their points of view or feelings about the issue with members of the

other class; however it readily became evident during the research that an informal interchange of ideas and concerns was taking place among members of the two classes outside of the classroom.

Preparation for the debate was organized into five stages:

Stage 1: Presentation of Background Information

Basic background information on cell division, and DNA structure and protein synthesis was presented during biology classes. It is my belief that students must have an understanding of fundamental content before moral and ethical questions are addressed. An understanding of what scientists can and can't do is tantamount to any discussion about the manner in which these new biotechnologies might alter society. It is for that reason that any discussion of causality which was supported by an erroneous notion of either the structure of DNA or the events of mitosis would be considered of little benefit to the forum. However that is not to say that everyone in the class must first possess a crystal-clear understanding of all of the content included in either the cell division or recombinant DNA unit. It has been my experience that many of these latent misconceptions become unvieled during the debate, and that many of these misconceptions are often identified and clarified by other students. The point being made then is that the class as a whole must have acquired some prerequisite knowledge about the topic, however expertise in the area is not essential for a discussion of social implications.

Stage 2: Introduction of Technological Applications

A presentation of the technological applications that arise from the development of scientific models and theories were introduced in an attempt to demonstrate the interdependencies of applied science and original research.

Aging was introduced by having students listen to an audio tape, commercially prepared by the American Chemical Association from their Man and Molecules series (1977), entitled "Hormones and Aging". The program consisted of an interview with Dr. George Roth, who outlined some of his research with aging drugs and predicted some of the potentials of this research.

The Recombinant DNA topic was introduced by way of a slide tape presentation. The presentation "Genetic Engineering" was prepared by Biology Media (Murphy, 1978). The focus of the program dealt with the mechanisms of Recombinant DNA, with special emphasis on the insertion of genetic information within the plasmids of a bacterium.

Neither program attempted to raise any controversial issues, nor did either program provide anything beyond a cursory glimpse at the potential benefits that would arise as a result of the research.

Stage 3: The Social Consequences

A scenario was presented as a means of initiating a social focus for the scientific research. The scenario used for the Aging debate, How Old Do We Grow, was developed by Addison Wesley Publishing Company (1984) as a social issue for their

Teacher's Resource Book for Biology (Kormondy and Essenfield, 1984). The scenario focuses upon a middle-aged man who has developed Alzheimer's Disease.

Students were asked to read the scenario and then consider the possible benefits and problems that a drug, which could suppress the aging process, might have upon society as a whole. It was generally accepted that a drug which could prevent Alzheimer's Disease would eventually be used to arrest the aging process for the rich and powerful who were not afflicted with the aging disease or that it would ultimately lead to the development of a corrollary drug which would prevent or retard their aging.

The social consequences for Recombinant DNA research were introduced within the context of the 1978 Cambridge debate in which Mark Ptashne's experiments of injecting genes from SV40, a cancer causing virus into E. coli bacteria were opposed by scientists from Massachusetts Institute of Technology and other universities. A tape of the debate was obtained from CBC radio's Quirks and Quarks (1978). Although one of the major points of contention, the escape of a hybrid E. coli from the laboratory, is no longer considered to be an integral part of the debate, many of the moral and ethical questions addressed during the town council meeting in Cambridge remain unresolved. Most importantly the Cambridge debate provided a dynamic model for the manner in which scientific interests and research have come to affect society, and reciprocally, the manner in which a society's perception of science regulates research.

Stage 4. Reflection of the Issue

Students were asked to reflect upon the social issues while considering the following questions:

Unit 1: Age Inhibiting Drugs

(i) Should scientists be allowed to do research on age inhibiting drugs?
(ii) Should an age preventing drug be discovered, who should receive the drug? Only those people suffering from Alzheimer's Disease? Only those who can afford it? Everyone?
(iii) Would this drug change society as we know it?

Unit 2: Recombinant DNA

(i) Who should decide what kind of genetic research is conducted by scientists?
(ii) What are the moral and ethical implications involved with the creation of hybrids? Are we controlling evolution? Do we control evolution in other ways?
(iii) Should a company be allowed to "patent" an organism it has created by Recombinant DNA techniques?
(iv) What are the social responsibilities of a scientist?
(v) Should bacteria with hybrid genes purposely be released into the environment? (Recombinant DNA Bacteria have been created that are capable of preventing the formation of frost on potato plants)

As part of the reflection process students were asked to do the following background readings:

Unit 1: Aging Drugs

Schock, Nathan, W. "The Physiology of Aging", Scientific American, January 1962, p. 100 - 111.

Unit 2: Recombinant DNA

Golden, Frederick. "Shaping Life in the Lab", Time, March 9, 1981, p. 48 - 55.

Kusenety, Marc. "Genetic Engineering: The Business of Changing Life", Science World, March 4, 1982, p. 12 - 15.

The readings were not designed as a device for formulating student opinions, but rather as a medium for re-examining and reflecting upon their own opinions. I do, however acknowledge the reading as a modifier of opinion, but I do not believe that the reading can completely formulate or mold a student's opinion.

Stage 5: Brainstorming Sessions

Students were given two alternates for addressing the questions presented within each of the social issues. Either the students could volunteer to partake in the debate or they could present their points of view in a paper, and then participate in the public forum after the debates.

Four students were chosen who supported the argument that scientists should be allowed to do research on Age Inhibiting Drugs or Recombinant DNA, and conversely another four students, who opposed this argument were selected. A coordinated approach was required and therefore small homogeneous group meetings were organized for brainstorming sessions. Neither the student teacher nor I became directly involved in the brainstorming sessions.

During the brainstorming session students were to concern themselves with:

> (i) how to best present their point of view;
> (ii) the development of questions to devalue the opposing points of view; and
> (iii) predicting the questions and objections that their opponents might raise against their views; and thereby either defuse them before they could be raised, or defend their opinions in light of these questions.

The Use Of Ethnographic Methodology During the Debate

Ethnographic research is more commonly associated with the descriptive fieldwork of cultural anthropologists and many qualitative studies by sociologists. The advantage of ethnographic techniques lies in the open-ended approach to research problems (Knapp, 1979). Rather than fitting the students into a preconceived format, the qualitative paradigm allows social interaction in as natural a classroom environment as possible. Bailey (1982) indicated that ethnomethodology provides an opportunity to study social interactions, and the manner in which members of a society make sense of "indexical" expressions. Indexicals are defined as terms whose meaning is not universal but dependent upon context. In this particular study the indexical expressions were those universalized descriptions about science and society, as described within the context of the debates on Aging and Recombinant DNA.

Aoki (1978) in describing a tri-paradigmatic framework for educational research identified the situational-interpretive mode as providing the evaluator with the opportunity to interpret meaning within the realm of individual experience. Wilson (1977) grouped both the situational-interpretive and critical theoretical orientations as emic-evaluations which he described as actor-relevant. Wilson (1977) believes that the qualitative researcher begins to understand human behavior by hearing participants express their perspectives in the flow of events.

The debate on "Age Inhibiting Drugs" took place within the

students regular biology classroom at a central high school in Edmonton. The eight volunteer students who were selected for the debate arranged their desks in a semi-circle at the front of the classroom. The students organized themselves in groupings, that allowed them to face their opposition, and the class members in the audience. Participating students were asked to alternate points of view, and a student moderator was appointed in order to assure that each side of the debate had an ample opportunity to express their views. Participants provided their perspectives and were then questioned by those who held a divergent viewpoint. A strict organizational scheme for presentation, questioning and defending of a viewpoint was not maintained throughout the debate, although the student moderators did intervene to make sure that the participants each had an opportunity to respond to the questions raised.

The debate was followed by a public forum, in which class members could re-address any of the points that had been previously made. During the public forum those students who had not actively participated in the debate either supported the perspectives that they had come to accept, or questioned those points of view that they had come to reject.

The debate was recorded on audiotape. The tapes provided a basis for the construction of interview-questions on the students' perceptions about the nature of science. By formulating the interview-questions from within the context of the "Aging Debate", rather than matching the students' statements to a predesigned check list, an attempt was made to

move towards a phenomenological orientation. Wilson indicates that for a researcher to adopt a phenomenological perspective, the researcher must attempt to understand human behavior within the framework in which subjects interpret their feelings, thoughts and actions (1977, p. 249). Roberts (1982) similarily indicates that the researcher must concern himself with both the event and the context in which the event occurred to achieve valid interpretations.

The Recombinant DNA debate was set up in much the same manner as the Aging debate. Students were again asked to identify either a "pro" or "con" opinion concerning the morality of research on Recombinant DNA. A concerted effort was made on my part to involve at least four new students from the previous debate. I decided to present the Recombinant DNA debate within the television studio at the high school, and thereby have the debate recorded on video cassette.

The color video recording has some distinct advantages over the audio recording in that non verbal communication can easily be identified by the researcher. Students who agree with the viewpoint being expressed can often be identified by a smile or a nodding of the head, while a frown or shaking head often denote disagreement. The video tape also provides a way of identifying excitement, frustration and anger. Another distinct advantage of the video tape is in the identification of participants. Audio-tape recordings make the identification of speakers much more difficult when large groups are involved.

The video-tape recording presents some limitations.

Students were much more conscious of the T.V. cameras and lights than they were of a microphone from a tape recorder, and thus, at least initally they responded in a much more cautious manner. Also, by placing the debate in a new environment, outside of the classroom, the context in which the debate is interpreted must be changed. The television studio cannot be considered a natural classroom environment. However, misintrepretation of nonverbal communication must also be considered with video-tape. A smile could indicate frustration or anxiety with a speaker rather than agreement.

A student moderator was not employed during the Recombinant DNA debate, however neither the student teacher nor I became involved with the proceedings of the debate in a capacity as either director or moderator. Other class members sat in the audience section of the Television Studio, and later were given an opportunity to address the debators by way of a public forum.

The questions from the Recombinant DNA debate were constructed after viewing the video tape. No attempt was made to either transcribe the "Aging Debate" or the "Recombinant DNA Debate" for the purposes of constructing questions. Rothe (1979) had indicated that the transcription of interviews from tape recordings took an inordinate amount of time. However central themes were identified from the audio and video tapes and then such portions were first transcribed in their entirety and later summarized.

In summary, the questions concerning student perceptions about the nature of science were investigated from the context of the debates, rather than organizing the debate to address the researchers's preconceived notions about the misconceptions that students hold about science and society. The paramount danger in first formulating a list of researcher conceived misconceptions, is that the debate may be affected. Rather than allowing the debate an opportunity to elucidate student perceptions about science and society, the debate might be orchestrated in a manner that would either verify or falsify the researcher's predetermined questions and thereby circumvent many of the more important perceptions that students hold about the nature of science.

It is my belief that the student perceptions about the nature of science are most effectively expressed and interpreted from within the context of a specific issue, rather than looking for a universally applied meaning.

The Selection of the Student Participants

Four volunteer students from each of my two Biology 20 classes were selected for a follow-up interview subsequent to the debate on aging. In that a large number of students had volunteered for the interview, the researcher selected two students who opposed the research on the aging drug and two students who supported the research. No attempt was made to have the groups represented by an equal number of males and females, nor did the researcher attempt to choose a

representative from the top 25% of the class and another from the next 25% etc. As stated previously the interview was not intended to show a cross-section of student attitudes about the nature of science, but rather a representation of the manner in which students formulate and express their perceptions about the nature of science, and the manner in which those perceptions are influenced by the science-related social issue that they are studying.

An interview followed both the debates on Aging and Recombinant DNA. The researcher's interpretations of student responses to the interview questions were validated by way of a follow-up interview session. The design of the follow-up validation will be dealt with in the next section of chapter 4.

The Aging debate occurred in mid-February, 1984, while the Recombinant DNA debate occurred in mid-March, 1984. The interviews took place ten days after the debate; with an additional validation follow-up interview taking place within ten days of the first interview.

The students were arranged into two groups that shall be referred to as alpha and beta. The alpha group consisted of four students.

Student M - was a student who achieved very high marks in the program and readily expressed his opinions during the Aging debate. This student did not know me prior to the Biology 20 program. "M" was involved in the Aging debate, but not the Recombinant DNA debate.

Student S - was a student who achieved average marks in

the program and readily expressed her opinions during both debates. This sudent was taught the prerequisite course by me. "S" was involved in both the Aging and Recombinant debates.

Student A - was repeating the Biology 20 program, however she was achieving above average marks during the course. She was very positive about the Aging and Recombinant debate. "A" did not know me prior to the Biology 20 course.

Student D - was also repeating the Biology 20 course and was not achieving passing grades during the course. "D" had poor marks in science related subjects in the past. He participated in both debates. He did not know me before the Biology 20 course.

The beta group consisted of the following four students:

Student B - a student who achieved average marks and who was involved with the Recombinant DNA debate. She readily expressed her views during both debates. "B" had been taught the prerequisite program by me.

Student K - achieved above average grades. "K" was involved as a debator with both debates. She readily expressed her view during both debates. "K" had been taught the prerequisite by me.

Student L - received high marks in all subject areas, and became involved with both debates as a debator. "L" did not know me prior to the Biology 20 program.

Student C - a very good biology student, although the same could not be said about all subject areas. She became actively involved with both debates as a debator. "C" had also been

taught the prerequisite course by me.

The Interview as a Research Technique

Michael Knapp (1979) indicated that ethnographic mini-studies can lead to insights into subtle features of program functioning, that would not normally be revealed by more traditional methods; however he also outlined some of the inherent difficulties in using a limited sample. Similarly Bailey (1982) identified the difficulties associated with conducting large scale studies within a qualitative paradigm. He indicates that traditional researchers often demand larger samples, often associated with quantitative survey research and therefore they are reluctant to accept many of the claims of quantitative researchers. Roberts (1982) explains that the appraising of qualitative research is exactly the same as that for appraising quantitative research; "the argument has to be made defensible" (p. 290). He indicated that the researcher has to rely on general analytical and argumentative skills.

By adopting a phenomenological orientation for the research many of the questions concerning sample size must be addressed. The focus of the research was not intended to determine what notions about the nature of science the majority of grade 11 students hold, nor did it attempt to elucidate what misconceptions the average high school student holds about the world of science. Bailey indicates that "large-scale mass-attitude studies are more appropriate for survey research than for ethnomethodology, both because they study product

rather than process and because they cannot be effectively studied with the observational methods preferred by ethnomethodologists" (1982, p. 299). This research, in contrast, focused upon the manner in which students had come to understand the nature of science by studying science-related social issues. The phenomenological perspective focuses upon the subject and their perception of reality; and therefore the manner in which individuals formulate their opinions about the nature of science becomes more important to this researcher than a cataloging or comparative statistical analysis of the end product of their thought. Bailey (1982) indicates that quantitative research is most appropriate if one is interested in studying some social product; however qualitative research provides an excellent approach for determining the process by which that product was derived.

George Psathas (1973) suggested three tests for ethnographic validity:

1. a) Are the findings faithful and consistent with the experiences of those who live in the situation?
   b) Are the findings accurate representations or interpretations of what those who lived those experiences would themselves recognize to be true? and,
   c) If second order constructs were translated into first order constructs to which they refer, would the observer's report be recognized as valid and an accurate account of what really happened?

The questions for the interview were constructed from the Aging and Recombinant DNA debates. These questions were not constructed in a manner that would provoke a re-hashing of divergent opinions as indicated within the debate. Instead, the questions focused upon the manner in which students perceived scientists and the scientific endeavor within the context of the science-related social issue. It was for that reason that students were informed about the purpose of the interview prior to its occurrance, and cautioned about the temptation to disagree with those who opposed their point of view during the debate, while supporting the perspectives of those who agreed with them during the debate.

The questions for the interview were constructed prior to the interview and a rationale was provided for each of the questions which outline what I had hoped to uncover for each question. An example taken from Appendix B, the Recombinant DNA interview, can best illustrate the manner in which the rationale for asking the question has been outlined.

1. In one part of the debate a student indicated that we must trust science and scientists.

(a) Why do you think the student gave that response? (or How did they arrive at that point of view?)

Reason for asking the question:

> Are students aware of divergent perspectives?
> Do they recognize that personal knowledge, individual values (Polanyi) affect what appears to be only a scientific decision?
> Can divergent pespectives be accepted and or appreciated?

For further examples refer to Appendix A, for the questions and rationale of the questions of the aging interview, and Appendix B, for the questions and rationale of Recombinant DNA interviews.

Many of the questions were constructed in a manner that would allow a "yes" or "no" answer; however a pause after the answer was employed to indicate to the participants that a reason for their answers was expected. Should the interviewee not volunteer their reasons for giving a "yes" or "no" answer I would eventually ask the student "why do you think so?" or "how did you come to believe that?". Bailey (1982) indicated that the respondent is often intimidated by the interviewer, and the the interview itself can provide a strained environment in that the respondent often attempts to provide the answers that the interviewer wants to hear. It is my belief that a constant barrage of "why", "how" or "what" at the beginning of the questions puts the respondent on the spot. By first asking their point of view and then allowing a pause the interviewee is given some time to formulate their thoughts and express their reasons for the answer that they provided. Therefore, the two-part approach was designed to provide a more relaxed environment. A second possible benefit of this approach was in providing the respondent with greater control of their answer. The use of "what" or"how" could draw the respondent towards the researcher's orientation of how the question should be answered, and thereby directs the response towards the researcher's perspective.

I also attempted to construct parallel and application questions that would verify previous answers. The following example is taken from Appendix A, Aging Drugs - as a controversial issue:

> Question Number 2. Can the new type of society that is created from this new technology, alter the type of research that scientists will do in the future?

This question was designed to identify the manner in which students believe that society alters science. The application question which appeared later in the interview was:

> Question Number 10. Why do you think more money is spent trying to find a cure for cancer than trying to control malaria and human liver flukes, which kill more people every year than cancer?

It should be noted that a respondents confusion about question number 10 does not indicate that a science/society interrelationship is not accepted but it does indicate something about the level of understanding and the degree of acceptance of that interrelationship.

Bailey (1982) has indicated that errors can result from transcribing the respondents answers during the interview. Drysdale (1983) also identified this problem of recording responses during the interview as being distracting for the interviewee and confining for the interviewer, because of ensuing preoccupation with writing and subsequent limitations it places upon observation. It was for this reason that an audiotape was selected for the interview.

The audiotape, although preferable to transcribing has many difficulties. Non verbal responses are not recorded

during the interview. The interviewer could inadvertently be shaking or nodding his head and thereby direct the respondents answers. The audiotape also makes it difficult to identify individual students should large group interviews be attempted. The logistics of voice identification prompted the researcher to use the respondent's first names very often during the interview. Restricting the size of the interview group to four respondents also helped overcome this problem.

Validation of the Interview

I reorganized the students into groups of two for the follow-up interviews. The alpha group was subdivided into two groups, group one with student D and M; while group two had students A and S. Similarly the beta group was subdivided with group three containing students K and L, and group four with students B and C. A follow-up validation interview was conducted within ten days of both the aging drug interview and the recombinant DNA interview. The smaller group follow-up session was designed to reduce the amount of time needed for the interviewees to validate their previous statements. The follow-up interview also provided students with an opportunity to reconsider their views, in light of the points of view expressed by other students.

The audiotape interviews were transcribed and used during each of the follow-up interviews. I found that if I read a student's response to the question for verification the student would indicate that, that was what they said. It quickly

became apparent that students were not really sure what wording that they had used ten days prior and were agreeing with my transcription without hesitation or reflection. It was for that reason that the design for validation of students perceptions was altered after the first follow-up interview for group one.

I decided to continue the re-reading of the transcript but followed the validation with the following strategies:

1. I asked the respondent if he or she still felt the same way.
2. I would change the wording of the response, and ask the respondent whether he or she still agreed with the answer.
3. An extension of the response was attempted. The most common format for the extension was by syllogism. (If you believe this to be true and that to be true then can we conclude that -----).

The follow-up interviews took approximately twenty minutes each, while the initial interviews took forty to fifty minutes each. I felt that a great deal of time was spent in the validation without the same benefit as the original interview, however the validation interview was nonetheless productive.

CHAPTER 5

INTERVIEW DESCRIPTIONS AND INTERPRETATIONS

OVERVIEW

INTERRELATIONSHIP BETWEEN SCIENCE AND SOCIETY/ DESCRIPTIONS AND INTERPRETATIONS

SUMMMARY AND CONCLUSIONS/SCIENCE AND SOCIETY

IMAGE OF THE SCIENTIST/DESCRIPTIONS AND INTERPRETATIONS

SUMMARY AND CONCLUSIONS/IMAGE OF THE SCIENTIST

A CONCLUDING RERSPECTIVE

REFLECTION

CHAPTER 5

OVERVIEW

The nature of science is a very broad topic, and as indicated in chapter 3, the definition of the nature of science will vary greatly depending upon the author's orientation. The components considered in this thesis focus upon student perceptions about the interrelationships of science and society. Through a series of student interviews, perceptions about science, scientists and society were examined and discussed. Unlike much of the previous quantitative research, where generalized questions about science were constructed independent of any specific scientific activity, my research has attempted to provide qualitative interpretations within a specific context. Interactive student debates on Aging Drugs and Recombinant DNA research were used as science-created social-issues, and introduced within the classroom as open-ended questions or concerns.

An interview followed each of the debates and student responses were recorded on audiotape. Later the responses were transcribed and my interpretations of their preceptions were verified during a follow up interview as indicated in Chapter 4. The data was then re-organized under two general themes. Rist (1982) suggested that a thematic analysis, the clustering of material by key themes, can be a very effective method for organizing qualitative data. Student interpretations were

reorganized into two major areas; the interrelationships between science and society and the image of the scientist.

As explained in Chapter 4, the focus of the questions was not meant to be a survey of student responses to the various questions that I formulated either prior to the interview or those additional questions that I asked during the interview. The intent of the questioning was to provide an avenue for investigating how a student comes to understand the nature of science. Therefore the number of students who indicate that science can change society is of lesser importance in this research, than are the questions that examine the manner in which they come to understand how society is influenced by science, or conversely, the rationale that they might employ to explain why society is not altered by science. It is for this reason that selected student responses will be presented within the interpretation of qualitative data, rather than a survey of the answers given by all eight respondents. It should be noted that dissenting opinions will be provided at all times to give the reader a complete picture. I recognize that the omission of alternate opinions would seriously mislead the reader and bring many of my interpretations into question, therefore those statements like "yeah, that's right", "I agree" or "Yes I see it the same way", will be omitted from data presentation and interpretation for the sake of brevity.

Interrelationships between Science and Society/Descriptions and Interpretations

A much levied criticism of school science has been its

apparent neglect of social issues in favor of content (Hurd 1982, Aikenhead 1980, Glass 1965). Students are said to lack an understanding of the manner in which science and technology alter society, and conversely the ways in which society and culture determine what kind of science is done, and the manner in which original research is applied. The Science Council of Canada in Report 36, Science for Every Student, has indicated that school curriculum can provide a more authentic view of science by including historical, social and philosophical dimensions in science teaching (1984, P. 37).

The questions approached within this research are concerned with student perceptions of the scientific endeavor when it is presented from within a social context. Upon completion of the first debate, which centered on whether or not we, (meaning the populus at large) should encourage scientists to do research on drugs that control the aging process; the following interview question was raised:

Interviewer

> Can science, through technology, affect society?

The following is a synopsis of the student views expressed:

C Very much so... Because everything we do like medicine, affects the way we live. Science affects the way we live... We could change the population's growth or the death rate (by using the aging drug).

A All science changes society, like computers are changing industry.

L Yah, science is always changing society. Every drug changes society.

Student C considers science to have a direct affect upon the way in which she lives. The example used to illustrate C's point comes directly from the Aging Debate, as the relationship between an aging drug, and the world's population is readily united. During the validation interview I asked student C why she had used population, and the problems associated with overpopulation in her answer. She indicated that the topic had come up during the debate, but that it was also being discussed in her social studies classes.

Student K also expressed the idea that science can change society, and used the computer industry as an example. The link established for this student is clearly between technology and society; however I make no claims about student K being able to link original theoretical research with technology and then society at this juncture. It is apparent, however, that student K is capable of applying a technology-society relationship beyond the confines of the Aging Debate. During the follow-up interview student K expressed the manner in which computers were changing society.

By stating that "all science changes society", student K provides an answer that expresses a great amount of certainty; however, it has been my experience that many high school students are prone to over-statements. Because of this tendency, I asked student K, during a follow-up interview, whether or not the phrase all science changes society was really appropriate. Student K quickly responded yes, but when I asked how the classification of chemical elements in a

periodic table, or the discovery of a new plant might change society, a much longer pause was taken and much less positive answers were given. It should be noted that the reluctance expressed by student K was in providing a reason for the manner in which the discovery of a new plant species or the ordering of chemical elements may affect society; however the certainty about science affecting society remained.

Student L suggested that every drug changes society; however when this statement was re-addressed during the validation interview, it became quite clear that the focus of the statement was directed to aging drugs. Here the expression "Every drug changes society" indicates the certainty that the student expressed within the context of the debate. When the notion of "every drug" was re-addressed within the validation, student L indicated that many drugs were not really considered. Student L became much more cautious about using the word every, but she also indicated that she could not think of any drug that did not change people, even if it was only a very small amount. She indicated that even if it helped one person, we could say that it changed society a little.

When I asked the beta group of students whether they thought that scientific research on aging could affect the family, student L provided the following answer:

L With the aging drug lets say that your grandmother is old and that. But if you had this drug, then no one would really be old. But it depends on what you would do with it (the aging drug).

Here science is identified as one factor capable of

changing society, but it is not the only factor capable of altering society.

From the alpha group, student A indicated that the aging drug would cause overpopulation, and that this would create more competition for food and jobs. Student M indicated that he believed that having people live longer would be good for the society in that older people have more knowledge, and that this would help society; however he disagreed with the consequences of less food. Student M indicated that this added knowledge might be used to make new foods; however his optimism was guarded. When student S indicated that the aging drug could give us an older society, that might resist change, student M agreed, and indicated that his answer presented only one of a number of different possibilities. The alpha group unanimously agreed that science can initiate a change in society, but that this was no way to accurately predict what those changes would be.

S - Science, like the aging drug, can change the way we live, but nobody can predict how it will change us - we can only guess.

The alpha group, as so aptly expressed by student S, acknowledged the impact that science has upon society; but they accepted this impact with much consternation, for they believed that the outcome of the change was largely unpredictable. For these students, science through technology can alter society, but science cannot tell us how society will be changed. Here an important limitation of the scientific process was uncovered by the students.

Robert Nadeau and Jacques Desautels (1984) express scientism as an attitude towards science that sees it as an activity that is based upon a time-tested method of solving problems. They indicate that the findings are unquestionable, should the analysis be scientifically valid. Nadeau and Desautels warn about the indescriminant use of a scientific paradigm for problem solving in the following statement:

> "Scientism is thus, in our view, both the attribution to scientific activity of an exclusive claim to legitimacy and the active belief that science itself justifies particular status, because a valid answer to any question pertaining to it can only be found through the application of its comprehensive method." (1984, P. 13, 14)

The students interviewed not only recognized the affect that scientific research may have upon society, but they have also come to understand the limits of science as a comprehensive method of problem solving. They agreed that the consequences of the research could not be accurately predicted, and therefore, at least one component of the research on aging drugs, the social impact, extends beyond the limits of scientific methodology. Science, for these students, is not an omnipotent problem solving strategy.

The view that science can alter society was followed by a question that asked the students whether this new society that is created by the presence of an aging drug could alter the type of research that scientists do in the future.

From the alpha group, students D and S indicated that scientists would probably continue to do much the same types of

research that they had always done, however students M and A strongly disagreed. Student M indicated that different types of societies do different research. He indicated that the Soviet Union and the United States are much more active in doing research that could be used for warfare, and examples of nuclear research, and development of chemicals used in warfare were given. Student M indicated that the Canadian society is very different than that of the United States, and therefore, its scientists are likely to pursue different type of research. One of the reasons given by student M for the lack of military-related-research in Canada, was the huge expense of such projects. It appears that student M regarded money as a primary determining factor. Student A supported the view of student M, and used the Aging Debate as the cornerstone to support her rationale.

A An older society has different needs. The aging drug gives us a different society.

The students within the beta group indicated that research would be different. Student C expressed the following rationale:

C There's more research going to be done on the old. Say better medicines for old people. More research on arthritis and other diseases that affect old people. The people that fund research will know that there are more old people so they will put more money in that area.

Student L supported this notion and provided another possible reason to explain how society influences the type of research that scientists do.

L Well, if we keep getting new technology

> then different things will be needed. Like arthritis may not be around, or any disease (that we know today - verified from validation interview). Then new diseases might be coming around, things like radiation. These new diseases can be caused by technology.

One of the weaknesses of the group interview is that a situation is provided in which the last interviewee to respond to the question has the opportunity to compare their answer with those expressed by other group members prior to their turn. Thus their answer may be modified or totally altered in light of the answers that the other students expressed. From the beta group students B and L agreed with the aforementioned points expressed by students C and K, but they did not offer any additional information. The interpretation of the data provided by students C and K therefore becomes much more difficult. Either they believed that the points expressed by B and L were so complete that nothing could be gained from them repeating a similar answer, or that a non-verbal clue was provided by the interviewer as the first answer was given. Students B and L may have interpreted a possible cue, as an approval for the correct answer, and decided to play it safe by agreeing.

Nadeau and Desautels describe a particular view of science as emanating from a philosophical orientation which they refer to as blind idealism. They describe the scientist as a lone figure purposely cut off from society to preserve objectivity.

> "The researcher is pictured as an individual cut off from all associates, deliberately severed from the rest of the world because of a refusal to accept the

> prevailing ideas of the time, seeking, single-handedly, to penetrate the enigma of certain events or phenomena... The scientist is commonly regarded as a person apart" (Nadeau and Desautels, 1984, P. 38).

The views expressed by students B and S indicate a close association with what Nadeau and Desautels refer to as blind idealism. For them the type of research done is primarily affected by the scientist, and not the society in which he or she finds themselves. Conversely the other students interviewed felt that society would greatly influence the type of research performed.

During the follow-up interview I asked all of the students; what determines the kind of research a scientist does? Both students S and D indicated that they believed that the individual interests of the scientist dominated. The other students, however provided socially based reasons; such as the desire to cure someone they know, a deeply felt social responsibility, the desire to make money, or the quest for fame and prestige. For students S and D, the desire to know, and the hunger for truth is the motivating force that predominates scientific research. Here the threads of idealism are made visible. Students S and D regard the scientist as someone above many of the influences of the common human being. Nadeau and Desautels provide an extreme perspective of this philosophy by the following statement:

> "The research scientist is envisaged as a pure spirit, a being on a higher plane, capable of remaining detached from the surrounding world and exercising powers of thought with complete objectivity,

> untroubled by the concerns that usually besets lesser mortals and distorts their perception of things. From this point of view, to be a scientist is to be untouched by material ambition, by the quest for prestige and glory..." (1984, P. 38).

By contrast, the other students believed that scientists are primarily motivated by social influences. Student L indicated that scientists doing research on the aging drugs were attempting to cure Alzheimer's Disease, and therefore motivated primarily by compassion, although she did not dismiss other influences like material reward and the desire for professional advancement as being contributing factors. Student M indicated that many scientists do what's considered high profile experiments to get worldwide recognition. For one reason or another, student M indicated that certain types of research come into style at different times. In many respects student M believed that science responds to specific trends, much like the fashion industry does.

An application question presented at the end of the aging interview asked the students why they thought more money was spent on cancer research than trying to control malaria and human liver flukes, which kill more people each year than does cancer. After expressing some surprise, the following answer was provided by student C.

C

> Probably because of the rich countries. Not too many people here in Canada suffer from liver flukes. The developed countries have the money to spend on research, but they spend it on diseases that affect our people. The underveloped countries don't have the money to spend on research.

Student C has not accepted the view of the scientist operating independent of the culture within which he or she lives. The image of a disembodied scientific mind has been put to rest by this student. However for students S and D, who continued to cling to an epistemological basis that Nadeau and Desautels referred to as idealism, the question proved to be much more perplexing. An interesting point is that although these students did not come up with their own answer during the initial debate, they accepted a modified version of student C's answer during the validation interview.

During the interview that followed the Recombinant DNA debate, I presented the following question.

Interviewer

> In one part of the debate a student indicated that we must trust science and scientists. Why do you think the student gave that response? (How did they come to that point of view?)

Whether the respondents agreed with that view or not, they indicated that the person who made the remark must have been very impressed with the many conquests of science, and recognized the great potential power for change that science possesses.

S

> Maybe the person who made that statement, but I don't agree with it, thought that science has done so much for us, that we just have to trust them.

The connection for student S, after the second debate, indicates an understanding of science, and the changes it brings to society. Even though she did not accept all of the social changes that have been influenced by science, as

inherently good; the impact of science as an initiator of change was well accepted.

K Because they have the knowledge to change things. If we don't let them use this knowledge then we won't move ahead and discover new things, or cure diseases.

Student K, like student S sees the potential for change through science.

D Well, you have to go through a lot to be a scientist, with University and everything they have to do. So you have to trust what they are going to do. You can't always be negative about scientists.

Student D, like student K acknowledges the specialized knowledge of the scientist and places his trust in science because of this knowledge. The students indicate that this knowledge is powerful, however student K based her reason for trusting science upon their past record, and the belief that science is a problem solver. Student D indicated that the specialized training that a scientist receives, should ensure our trust in science. For student D, scientific research has a special status, not because of its past record, or the manner in which it has changed society, but rather because it holds a mystique. During the validation interview student D indicated that he has always found science difficult, and thought that scientists had to be very intelligent. The reasons he gave for the statement, that we must trust scientists, projected his admiration and respect for those who could understand this way of thinking. While the other students examined the social impact of past scientific activities as a rationale for the statement, student D used a different criteria for looking a

scientific research. The point being made then is not whether or not student D's assessment of why the student had come to that conclusion was correct, but merely that student D used a different orientation when approaching this statement about science and society.

During both the Aging Debate and the Recombinant DNA debate, questions of scientists' responsibilities arose. The interview provided the opportunity for students to address the responsibilites that a scientist has to the society in which his or her research is conducted. The following question was presented during the Aging Debate:

Interviewer

> A scientist suggests that his function in society is to find a drug that slows the aging process. How that drug . . is administered or who gets it, is beyond his control. The scientist in question explains that he is not a politician, and therefore his social responsibilites do not extend beyond making sure that the drug is medically safe. Do you agree with this view?

All the students in the alpha and beta groups strongly disagreed with this statement. Student D from the alpha group indicated that the scientist bore a special responsibility in that he could best understand how that drug might be used. Along with the specialized knowledge came a great moral responsibility, according to student D. Student C indicated a similar perspective and explained that along with the power for change comes the responsibilities for change. It was expressed that scientists do not pay enough attention to the social consequences of their research, and nuclear research was

identified by both groups as a cogent example. The scientists doing research on nuclear fission were described as naive, but not totally to blame. They recognized that politicians encouraged this research, and that society in general must also bear some of the responsibility for letting it proceed.

In the area of social responsibility the students were able to define some of the limits of science. They explained that science has a responsibility to make sure that the changes that it institutes are in the best interests of society. However, they also indicated that science was not the sole initiator and determinant of change. Science, was described as a social activity by these students. Their understanding of the manner in which society affects the type of science done in a particular culture was expressed very strongly, even by the students who had initially suggested that science operated according to the interest of scientists. This became even more evident when the interview discussion turned to nuclear research. Student D indicated that scientists alone are not responsible for the way in which their discoveries are implemented, but that they do carry a definite responsibility. At this juncture, student D indicated a movement away from the idealistic orientation of the scientist working independent of society. His response indicates a questioning of the view which suggests that scientists should operate without social pressures and influences. In abandoning the idealistic perception, the scientific endeavor is seen as a social activity, and, as in the case of nuclear research, it is only

when the scientist attempts to remove himself from the social responsibilities of his activities that scientific knowledge becomes truly perilous.

Summary and Conclusions

The interviewed students drew many of their examples from the debate. This became even more apparent when a longer pause took place between the question and the answer, indicating that the questions which students found most difficult to answer were most appropriately approached from within a specific context. Therefore, I believe that the debate provided an important reference for the students when they considered the interrelationships between science and society.

Statements like "all science changes society" and "every drug changes society" arose during the interview session. The tendency to universally apply many of the characteristics of science, in reference to those uncovered during the social debate, remained throughout the interview. By utilizing the debate as a reference point students tended to overstate the characteristics of the nature of science, and often applied them without first considering if all science operates in the same manner. The doing of science for an eighteenth century taxonomist, and a twentieth century molecular biologist is dramatically different, and intrinsically unique.

Despite this apparent problem, the debate provided many benefits. Students used the social debates as a way of approaching the interview questions, and continually extended

beyond the confines of the debate; incorporating science issues like the quest for a cure for cancer, the implications of nuclear research or the need for new sources of energy. The very nature of the debate presented a model for students to compare other areas of scientific research. The manner in which scientists operated in Cambridge, Massachusetts during the town council debate, provided an insight in the manner in which scientists interact with each other, and how they influence and respond to the culture in which they live.

During the debate on aging the students used information on population and food production, which was presented in their social studies class, and later used these points within the interview to describe how science affects society. Thus the debate presented a focal point that allowed for the extensions of other scientific activities, while providing the opportunity for the infusion of social issues.

All of the students interviewed indicated that science affects society. Again, with reference to the Aging Debate, they identified applied science as a dominant causal agent, however they did not describe science as an exclusive initiator of change. Student L indicated that an aging drug would alter society, but how much it changed society would depend upon how the drug was used, and who was allowed to receive it. The administrators, and implementers of applied science share in the evolution of society for this student. For students who hold this view of science it is unlikely that they would ascribe all of the successes of man to science and technology,

nor would they be as likely to impute our failures solely upon the shoulders of science. Many of the rising public fears about science (Handler, 1980) may well stem from an image of science and technology as an exclusive purveyor of change. Student L identified science in a cultural economic and political milieu, and therefore, as one of only a number of components that interact to bring about change. Science, in this view, does not act upon society in addition to economic and political factors, but operates within a political, moral, economic and social domain.

Despite the positive and unanimous assurance that science can indeed change society, no such concensus prevailed when students were asked whether or not society could determine what type of science was done. Although some students quickly acknowledge the interplay between society and science, others felt that the interaction between science and society was unidirectional; where science could affect society, but society had very little impact upon science. For students S and D, the difficulty in perceiving the ways in which society influences science indicates a particular view of science. Their perceptions of science acting upon society, but their denial of a reciprocal interaction suggests the view of science above society. Nadeau and Desautels (1984) indicate that this perception of science outside of society stems from a specific philosophical orientation, that they referred to as blind idealism. This espistemological framework places science above the influences of modern society, and raises the scientist to a

mystical level far beyond the lure of power and money, untouched by political compromises and the quest for prestige.

Students who held the idealistic perspective, as described by Nadeau and Desautels (1984) were drawn into conflicting statements. When asked whether or not a new society might promote a different type of research, students D and S indicated that it would not. They believed that scientists themselves decide what they will research, and that their research comes from the special qualities and abilities inherently present within the scientist. However when student M indicated that more money is spent doing cancer research than on liver flukes or malaria, because of social and political influences from industrialized nations, students D and S agreed. Yet in this example society clearly influences science. The idealistic perspective of a science, as a higher form of knowledge, operating apart from society is drawn into conflict with what they have accepted as an answer to the interview question on cancer research.

An interesting observation at this point is the fact that students D and S had a much more difficult time answering application questions that supported a society--science relationship, than was experienced making the science--society relationships. The philosophical perspective of blind idealism (Nadeau and Desautels, 1984) remained firmly entrenched through both interviews in spite of the inconsistencies it produced. This supports the previous finding of Beardslee and O'Dowd (1961) that misconceptions about the nature of science remains

firmly in the minds of students for many years, and the paper by Nadeau and Desautels (1984) which indicates that a conceptual philosophical basis underlies a students perceptions about science.

It should be noted that although students D and S held what has been identified as an idealistic epistemological preconception of the world, threads of this same philosophical orientation were found during my interviews with the other students and with myself. By categorizing a particular viewpoint within the idealistic domain, it does not automatically polarize the responses as either idealism or realism. I feel that little can be served from categorizing student responses into an artificial dialectic. On the contrary, responses move along a continuum and perceptions are transformed not only by the social debates, but by the interviews themselves. Therefore, the perceptions of students S and D have been associated with a philosophical basis that enables me to explain how they come to understand the relationship between science and society.

Students who acknowledged reciprocal interrelationsips between science and society came to understand science within a cultural milieu. For them science is pre-eminently a social activity. Student L indicated that scientists alone do not decide on how the aging drug will be used, and therefore scientists do not have complete autonomy for decision-making. Later in the interview she explained that scientists can not predict how the aging drug could change society. Therefore,

the scientific paradigm is limited to the problems it can solve. A similar view of science was expressed by student M, who rationalized that the impacts of Recombinant DNA research may not be felt for many years to come. He indicated that the movement of molecular biologists from the universities to private industry would transform the very practices of science, as patents and the fear of being scooped by rival competitors would seriously deter the exchange of information and tend to direct science inwardly. Although student M did not deny that individual ego and a quest for notoriety and acclaim already has established a basis for secrecy, he felt that the intensifying economic realities would be pernicious to those involved in scientific research.

For these students science is not an omnipotent problem solver. Science, as a methodology, has its limits, and only retains veracity when applied to scientific problems. Glen Aikenhead (1980) indicates that effective science teaching must provide students with situations in which the limits of science can be understood. He rationalizes that:

> "... science is limited to answering scientific questions. This makes science alone inappropriate for answering economic, ethical or political questions, such as whether it would be better to invest in nuclear power or in coal-fired generating stations to produce electricity." (Aikenhead, 1980, p. 32)

Image of the Scientist/Descriptions and Interpretations

The image of the scientist among high school students (Mead and Metraux, 1957) and college students (Beardslee and O'Dowd, 1961) has providied a basis to understand why students

hold a limited view of science. Mead and Metraux (1957) described students as perceiving scientists as cold, unemotional men, capable of detaching themselves from their environment and acting objectively as they set up their experiments and collect their data.

I believe that a student's perception of the nature of science can be elucidated by investigating how students perceive the scientist. The image of the scientist as a singular researcher, operating within a laboratory, driven totally by the quest for knowledge, has been well documented (Mead and Metraux 1957, Beardslee and O'Dowd 1961, Korth 1968, Mitias 1970, MacKay 1971, Hurd 1975, Nadeau and Desautels 1984). What remains to be investigated in my study is the manner in which the social debates have affected the manner in which students come to understand the nature of science through their perceptions of the scientist?

The questions as presented during the interviews following the debates on Recombinant DNA and the Aging Drugs have been re-ordered and integrated for the purpose of interpretations. Refer to Appendix D for the re-ordering guide.

The first component that I approached is the way in which students imagine a scientist would appear.

S I think the scientist, at least for Recombinant DNA, would be quite young or middle aged. He would have to be young because older people would probably hold back on these kinds of things.

M Well, the Recombinant DNA scientist would likely have been a teenager in the 60's. He'd have longer curly hair, blue jeans - you know.

The descriptions of the appearance of the recombinant DNA scientists came quickly to the students. By general concensus the scientist was most often described as young and male by both male and female students. The young image, as presented by all but one of the students interviewed lies in opposition to much of the previous research. The connection between the scientist and the modern era is very clear for student M. The blue jeans and longer curly hair indicate a close contact with style and fashion. Therefore, for student M the Recombinant DNA scientist is very much a part of the society in which he lives. Student S indicated that her descriptions aligned very closely with the Recombinant DNA scientist, however she went on to distinguish molecular biologists from the scientists who did what she referred to as normal research. During the validation interview I asked student S what she meant by normal research, and she indicated that these were the ordinary things that are talked about in chemistry and/or biology classes. These scientists, in the view of student S would conform to the stereotypic image of old; an unkempt appearance, and forever absent-minded.

Student C described the scientist, who does research on Recombinant DNA, as being young and a smart dresser. For student C this scientist would have to be presentable, a very good speaker, dynamic and forceful. She felt that because this branch of science was so new, and because it was so controversial this scientist would have to be a bit of a salesman. Therefore, according to student C, the scientist

would not only have to be a good researcher, but he must also project a positive and convincing image to the public, one that conveys trust. Like the description of the scientist given by students M and S, student C closely associated science with social influences. For student C the scientist has to operate within a business environment, and like any other activity that operates from within the confines of a social structure, the scientist requires interpersonal skills and is judged not only upon the quality of his research but upon the image that he projects. For these students, science is inextricably linked with the economic influences of society.

Throughout the interview students identified characteristics that distinguished the appearance of different scientists. The Recombinant DNA scientist was described as a rebel or business executive, while other scientists seemed to fit the stereotypic appearance described by those students investigated by Mead and Metraux (1957). I believe this indicates that the social debates provided students with either an alternate or additional perspective from which they view scientists.

Students also rejected some of the mild and retiring personality traits normally ascribed to scientists.

M I think that the scientist would have to be aggressive and very forceful. He sure wouldn't be shy, or he would never get anything done. (In reference to a molecular biologist).

Interviewer

Would the scientist be absent minded?

M I don't think any scientist is really absent-minded. How could he be? He would never get his research done. That's just the kind of stuff they put on T.V. to be funny.

An exception to the view of the scientist provided above should be noted. Student D described the molecular biologist involved with Recombinant DNA research in the following manner:

D I think he would be older, with grey hair and maybe a beard...he would have to be old because it would take a long time to gather all that knowledge and do that kind of research. He couldn't just start doing this without learning a lot of things first.

The image provided by student D was of an older man consumed by his interest in science. Although he did not describe the scientist as an isolated researcher cut off from society, untouched by the lure of money and power; he rejected the image given by students M and S. Student D felt that the scientist was primarily good at science, and that the blue-jeaned image rebel provided by student M or the business executive profile, were very unlikely.

The view of science as a long arduous completion of facts was provided by student D. For him a scientist must accumulate a great amount of information before he can progress. This notion is so well developed by science teachers, who indicate to students that a thorough mastery of all of the content in a particular unit is essential before any laboratory activities are attempted or debates can even be considered. Student D has come to accept this notion of science as a linear progression from known facts towards research. He believes that the

accumulation of vast factual information is very long and difficult, and therefore only older men can do the research. After the last interview I talked with student D and told him that Francis Crick, the co-discoverer of DNA, only went into graduate studies in science at 29, and made his enormous discovery at an age of 31, before receiving his Ph.d. Student D expressed surprise at the idea that Crick was so young, and also at the information that he had done other things before returning to science.

Question number 6, taken from the interview that followed the debate on recombinant DNA asked the following question.

Interviewer

> Is it possible that one scientist could indicate that we should do the research while another suggests that it should not be done?

S

> Yes that can happen, like A (student A) agreed with the research on aging but I didn't. Even if we were scientists, it depends upon how you feel. They can still take different sides of the argument and look at it from the way they feel. They can try to be totally objective, but you can't be totally objective.

C

> Scientists can have different opinions. They are people just like you and me. Everyone has different opinions about different things,...

B

> (Reference to whether or not research on the aging drug should be encouraged). Oh yes, they may look at different aspects. They have personal feelings. One could be looking at just the little boy (suffering from a rare aging disorder), while the other may be looking at a perfect generation...they just start from different points of view.

All of the students believed that scientists could

disagree. Scientists, according to the interviewed students, do not all think the same way. Therefore, science is not a pervasive form of thought that regulates or predetermines a specific conclusion. The students recognize that a scientist comes to look at issues from a code of morals and a set of many personal experiences that clearly extends beyond the confines of science. These personal or subjective factors come into play, even when scientists are considering whether or not the research on aging drugs is appropriate. Student S indicates that scientists attempt to look at a particular viewpoint from an objective stance, but she quickly acknowledges that this has only limited success, since subjective factors can never be fully eliminated.

This interpretation is supported by other responses. Students were asked whether or not people, who were pro science would be more likely to encourage Recombinant DNA research. The reverse question was also asked. (Refer to appendix B and see questions 2 and 3). Although a pro-science and anti-science attitude was accepted the students indicated that they did not believe that research could be supported or rejected on the basis of an attitude towards science. Student K explained that just because someone is a scientist, it does not necessitate their unqualified acceptance of all scientific research. Student A believed that a scientist might tend to be the most critical of new research. Again the students have rejected the idea of science, as a methodology which determine the decisions made by scientist. Students K, L and C all

indicated that their views on the Aging Drug and Recombinant DNA debates indicated that the decision to encourage or discourage any particular type of research depended upon subjective factors, rather than an attitude toward science.

Student K and L encouraged recombinant DNA research however they were opposed to research on the aging drugs; while student C supported the research on aging drugs but objected to some aspects of recombinant DNA research.

Students expressed a guarded optimism towards the benefits of science and technology. Although they indicated that scientists have generally improved the conditions of mankind, they did not look upon science as an omniscient problem solver.

Interviewer

> A proponent of the research suggests, that if science is smart enough to stop the aging process it could also control overpopulation, food shortages and other consequences of increasing the age span. Do you agree? (See Appendix A, question 9).

C

> Scientists invented the birth control pill to control the birth rate, and they have decreased the death rate. But scientists can't as a whole, although they can help, change the world unless people -- like countries are behind them.

Student C acknowledges that contributions of science in controlling the population, but she also indicated that overpopulation and an escalating birth rate remain in certain areas of the world. A social factor, such as the cultural pressures to have large families, can counterbalance new discoveries in science. Student C indicates that the aging drug may well lead to longer lives, but that people may choose

not to restrict the birth rate any further. Here the availability of a technological answer to the problem does not necessarily ensure a solution.

K Scientists can help us use things, but what happens if like all of the natural resources are used up. They can't make new resources. You can't make water, or oil and food.

Interviewer

But they are coming up with new food sources. ...

C They probably are smart enough. Technology is advanced enough, but the point is who is going to fund this.

Student K indicates that science has its limits. Scientists should not be expected to make new water, oil or foods. Despite the many triumphs of research Student K is not willing to abdicate the future of the environment on the notion that science will solve all of the problems that it creates.

Student C calls into question the very reasons for doing research, and emphasizes that money is a very large factor. Student L accepts this concern and adds:

L The money spent on research comes from the rich. Maybe the aging drug would only benefit the rich.

Student L provides a very strong statement which indicates that she understands how science serves the culture in which it operates. For both students C and L, my comment that technology has developed new sources of food, did not sway their opinions. Student K responded to my assertion that scientists have developed new foods by stating that the new food may not be nutritious.

K Is this new technology food, like from garbage; is it really healthy? Sure its a new food source, but is it any good? A powdered food that you only add water to; is it any good?

Here student K uses an example taken from the debate to help explain her position. Although the idea of garbage being converted to usable food substances was introduced by a student who opposed student K's position, she seized that information and presented it within a critical analysis. For student K a technological solution to the problems created by science must be examined carefully to disclose the quality of the answer. The fact that the new food source is introduced does not indicate that the problem is solved. The solution itself may well prove to be the originator of many other problems. When Student K indicates that the new food may not be healthy, the possibilities of it creating problems associated with malnutrition or inducing cancer have not been ruled out.

None of the students interviewed were willing to accept either science or technology as an omniscient problem solver. The students who felt that society acts upon science indicated that scientific research requires a social responsibility, because it functions within a social domain. Student C acknowledged that science may well be capable of solving world food problems, but she doubted that the society which promotes research would be too willing to fund it. Student L was even more blunt when she indicated that the money for research comes from the rich, and therefore science would be directed towards the problems which face a richer society. The scientist then

is greatly influenced by the needs of the culture in which he or she lives. The idealistic perspective which indicates that scientists are primarily motivated by their unending quest for knowledge (Nadeau and Desautels, 1984, p. 38) is not accepted by the students who feel that the scientist works within a cultural setting.

It should be noted that students D and S, who I identified earlier as retaining the idealist philosophical perspective towards science, had great difficulty in formulating an answer to this question. Student S indicated that it would be difficult to trust technology without any proof that it could create new foods. By asking for proof student S might have assumed that science could indeed provide proof. Should this be a correct interpretation of the statement made by student S, I would conclude that the limits of scientific methodology are not well understood. Student S is attempting to use science to foresee the future advances of science and technology. By asking for factual evidence student S maybe indicating that science can do more than predict the future, it can foretell the future. Because science deals in facts, student S indicates that factual information can be provided. This view of science as a compilation of pre-existing factual information is intertwined throughout the statements by student S. Although she may not accept science as a potential solution to all science or technology created problems, she believes that science provides the best avenue to follow, if we are to solve these problems. This view was also verified during the

validation interview.

Student D indicated that he wasn't sure whether or not science would be able to solve the problems that it created. Student D, however did indicate that the views expressed by M and A, who viewed the scientist in a social milieu, seemed plausible. I do not believe that this single question changed student D's idealist philosophical orientation, but I do believe that it provided a contextual format which initiated a reassessment of his perceptions about science and scientists.

Summary and Conclusions/Image of the Scientist

The interviewed students who viewed science as a social activity described the Recombinant DNA scientist as a young, dynamic individual who would be very much in tune with society. Their view sharply contrasted the stereotypic image of the recluse genius, toiling in a secluded laboratory as reported first by Mead and Metraux (1957). The majority of the students indicated that the molecular biologist involved with such controversial research would have to present a confident and positive image to the public. For society would be very unlikely to support the research proposed by either an individual or a subculture that was isolated from social realities. Thus the crumpled suit, the uncombed hair and the shy retiring manner would convey an unawareness of social concerns and possibly an indifferent attitude towards the changes their research might create. The scientist, totally consumed by his research would have limited scope, and for

these students, be unable to convince the general public to support his research. Science, and to a greater extent high profile research, operates within a socio-political setting. The scientist, according to these students, must operate within this cultural setting, and therefore, in order to be successful, the scientist must be aware of the social consequences of his research,and be willing to accept some of the responsibility for the changes that the research causes.

Some of the students indicated that what they considered to be less controversial research might be dominated by the more stereotypic image of a scientist. Student S explained that other kinds of scientists doing more conventional research might be less dynamic than the molecular biologist. Later she indicated that those that have done research in the usual types of things discussed in chemistry or biology classes may fit the stereotypic image. Student S felt that molecular biology was capable of changing society greatly, but the strong relationship between science and society was not as evident for all branches of science. I believe this indicates that when science is presented to a student as isolated static facts, the teacher conveys a very different image of science and the scientist. Joseph Schwab recognized this all too prevalent approach. Schwab indicated that, all too often, traditional presentations of science have been concerned with scientific knowledge expressed as a "rhetoric of conclusions" (1964, P. 24). Leopold Klopfer voices a similar criticism in that he feels that "science is presented as a body of knowledge which

is static and proven true" (1976, P. 564). The interactive debate looked beyond the conclusions of experimentation, into the social consequences of scientific research, and here student S found a very different type of science. The Recombinant DNA biologist or the researcher working on the aging drugs provided no true conclusions, nor could this form of science be finalized with a right or wrong answer. Scientific research presented in an interactive social context creates a different view of science and the scientist.

Student D rejected the image of the young dynamic scientist. For student D science is a very complicated process that requires long enduring years of study to accumulate vast quantities of factual information before beginning any research on something as new and revolutionary as Recombinant DNA. Student D found science a difficult subject, and he was in awe of the scientist who could master such a complicated maze of knowledge. I believe that this notion of science is often nurtured by science teachers, who indicate to students that a thorough mastery of all of the context in a particular unit is essential before any laboratory activities are attempted or debates undertaken. This all too prevalent attitude among science teachers tends to elevate their worth in the eyes of many students, because they have accumulated what many students consider to be great quantities of scientific information and they hold the key to this ubiquitous maze. But their elevated prestige comes at the very expense of those students who find science a difficult perplexing subject.

In the previous section on the interrelationships between science and society, I had indicated that students D and S presented an idealistic philosophical orientation to their view of science. Nadeau and Desautels (1984) describe the separation of the scientist from society, as he operates alone and tirelessly in a laboratory. The idealistic perspective portrays a man untouched by the social influences which motivate mere mortals. The scientist is motivated only by a quest for knowledge. Here the very basis for student D's idealistic perspective can be uncovered; for he indicates that science is very difficult, and therefore requires a special type of person to undertake such an arduous task. The scientist, for student D, must clearly be someone very different than himself.

A Concluding Perspective

As I began my thesis and compiled the research literature I held a particular perspective on what the nature of science was. However, as my research continued, the topic itself began to mean something very different to me. I was originally quite willing to compare student perceptions about the interactions of science and society to a predesigned list of correct answers. That is the starting point of many of the researchers entering this field. However it became readily apparent that a comparison of student responses to a set of author approved or author created answers did not provide answers to the questions that I was really interested in knowing. The correlation of

student answers to author answers assumes that common indexicals, (Bailey, 1982) or sets of meaning are shared by the author and the student. It also assumes that the context in which the author interprets a particular event can be conveyed to the student. As argued earlier, I believe that the nature of science is contextual rather than generalizable. The final assumption is that the researcher's answers are truly correct, no matter what the context, and that any answer which diverges from the author's are seriously flawed. My research has focused upon the ways in which students come to understand the nature of science when it is presented within a context of social issues. Therefore, the student perceptions that I indicated become relevant only when science is presented within a social context.

An assumption made by many researchers is that the nature of science can be universalized, and thereby isolated from the social and cultural milieu in which it occurred. Thus the doing of genetics for the Austrian monk, Gregor Mendel, in the 1870's and for molecular biologist, Paul Berg, in the 1980's can become commingled when identified by a generalized multiple choice question. By looking only for universally applied similarities, as do the originators of these multiple choice questions, a reductionist's view of science is perpetuated. This orientation denies the divergent personalities of the two men, and the social influences that motivated them. By asking only what is similar we deny the subjectivity of the endeavour. The type of research conducted is greatly affected by the

individual undertaking it.

By looking for a question that is universally applicable to all scientific activities we make the epistemological assumption that science exists as an objective reality; where the subject or individual becomes a vehicle to attain pre-existing truths. From this perspective the subject becomes subordinate to these truths which exist in an object world. This reductionist perspective allows us to proceed from observation, by generalizations to the truth. When generalizations become the primary concerns of researchers, the focus upon the nature of science becomes hinged on similarities, and phenomenological differences are ignored. Once social setting, researcher bias, and cultural influences are either generalized or discounted, as they often are by multiple choice or true and false questions; questions about the nature of science become detached from the personalities of the scientists and isolated from social concerns. Science becomes an object to be understood, rather than theories and models constructed and interpreted by a living subject.

It is my belief that the scientific enterprise is not the same for all scientists; nor can researcher bias or cultural influences be generalized for all activities. The influence of parents, religion and peers for a scientist engaged in the high profile areas of molecular biology or nuclear fission is likely to be different than for a researcher classifying plants along the Amazon river. To acknowledge researcher bias, without first considering the context in which the research is

performed, promotes the myth of scientism. When the phenomenon is extracted from its surroundings, we are left holding the threads of empiricism and a reformulated methodology, that may vary greatly between researchers. Empiricism and the scientific method exist within an objective world. It should be noted that only the knowledge gained from an objective reality can be generalized, in that subjective knowledge resides within the individual. Objectivity, because of its generalizability becomes dominant over subjectivity.

Hubert Dreyfus (1979) indicates that the tendency to separate the noema (that which is experienced) from the noesis (the mode of experiencing) is well entrenched in the Western philosophical tradition. He states:

> "It starts with Plato's separation of intellect or rational soul from the body with its skills, emotions and appetites. Aristotle continued this unlikely dichotomy when he separated the theoretical from the practical, and defined man as a rational animal - as if one could separate man's rationality from his needs and desires" (Dreyfus, 1979, p.62)

It is for this reason that a concerted effort was made on my part to investigate student perceptions about the nature of science within the context of the debates on Aging Drugs and Recombinant DNA. It should be noted that the views expressed by the individuals are relevant to only those two debates, and may have varied should other debates have been chosen. The debate provided a context, in which students could express their perceptions about science, and I could explore how those perceptions came to be.

Reflection

Like most qualitative research that I have read, my thesis ends by asking more questions than it resolves. My research indicated that by presenting science within a social context, students provided me with a less naive perspective of science and the scientist than did the students investigated by Mead and Metraux (1957), Beardslee and O'Dowd (1961), Korth (1968), Broudy (1969) or MacKay (1971). However I did not prove that it was the social-issue debates that contributed to students gaining a more realistic perspective of the nature of science. Students today may well have a better understanding about science than did their predecessors. It could also be possible that the investigative techniques used by the other researchers I have indicated above might have been a major contributing factor to their assessment. When I surveyed many of the multiple choice tests I found a number of questions that could be interpreted from divergent orientations. I could justify any number of different alternates for some of these questions. Unlike the authors that constructed these questions, I felt that the answer could vary in accordance with the context in which the scientific activity occurred.

My research did indicate that students interpret the nature of science within the realm of individual and shared classroom experiences, but that they also bring values and an epistemological orientation to these experiences. I had indicated that student D and S had an epistemological orientation that Nadeau and Desautels (1984) identified as

"blind idealism". Although I prefer the description as extreme idealism, it was used to indicate a consistent philosophical orientation towards the nature of science. I did find however, that all of the students interviewed, presented threads of an idealistic perspective from time to time during the debate.

An important finding was the manner in which the debates and interviews themselves brought the idealistic perspective into conflict. Student S and D continually soften their idealism. Thus I believe that the interactive nature of both the debate and interviews acted as a modifier of what I have referred to as this epistemological orientation.

The questions that have been raised during my study, but remain unresolved, deal with the manner in which the interview itself modified a student's understanding of science. Philosophical questions are rarely asked in class, nor are students given an opportunity to express their opinions about the nature of science. What viewpoints about science and the scientist that the students in my research held, are dependent upon the interactive issues - debates or the interview precess itself.

My research topic, an investigation of student perceptions about the nature of science is vast, and consequently not all of my findings are specific and conclusive. Rather than bringing closure to the topic I believe that my research has opened up many new avenues for further research by identifying sign posts or tendencies. By indicating that the students I investigated did not possess as naive a perspective as reported

by other researchers, I did not provide a confirmed answer.

My research does indicate some of the potentials for an integration of science and society within the curriculum. Like any implemented curriculum its success lies within the teacher and most importantly the learner. The most important point to be made here is that the teacher and the learner are not designated roles within the classroom. The student-debator as presenter is both teacher and learner, while the teacher as observer also takes on dual roles.

The implications for teaching include the introduction of social issues into classrooms within an interactive format, and the inclusion of philosophical discussions about the nature of science. The assumption that a scientific discussion requires more than just a basic conceptual understanding about the topic is seriously flawed. Students in social studies classes are often encouraged to express their opinions on world affairs without any expertise in that area. Discussions and opinions about sport are often solicited from individuals without athletic ability or prior experience in that sport. By seeking only the opinions of scientists, and dismissing the non-expert opinion as inconsequential, the notion that science exists above other disciplines is perpetuated. Science, according to this idealistic perspective, affects society, but a reciprocity of society acting on science is negated because of its superordinate status. Teachers who indicate that all of the facts must be gathered before a laboratory experiment is begun or a debate initiated, reinforce this perspective. Science not

only becomes a linear progression of pre-existing facts to the truth, but for many students subjected to this presentation it is often conceptualized as an endeavor isolated from society. From my perspective, science must be presented within a social context. What remains is to monitor the potentials of the interactive debate, and develop other strategies that allow classroom science to be presented in a more realistic fashion.

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APPENDIX A

AGING - CONTROVERSIAL ISSUE

Central Question

- Should scientists be allowed to develop a drug (or isolate a hormone "endorphine" that would affect the rate at which cells deteriorate and reproduce?

Interview questions

1. Can science, through technology, affect society?

- question is approached from within the confines of the science-related social issue - aging.

- the question is designed to elucidate a student's perception of manner in which science, technology and society are interrelated.

- a great deal of information concerning this question has already been gleaned from the forum (debate) on aging. However this question may illustrate the formulation of generalizable notions about science/society.

(a) How can society be changed by the invention of a drug that alters the aging process?

- question may not have to be asked depending upon the answer given to #1.

- again much of this information was evidenced from the debate, but the question may serve to focus the student's responses upon the proceeding of the debate and verify the initial statements as expressed with the forum.

2. Can the new type of society that is created from this new technology -- research, alter the type of research that scientist will do in the future?

- this question will only be asked if the response to question #1 is yes. The forum indicated that students believe this to be the case.

- this question is designed to illustrate the effect that society has upon the type of research that is performed.

- a check question -- heart disease and cancer -- asked later is designed to verify or re-check this question.

3. A scientist suggests that his function in society is to find a drug that slows the aging process. "How that drug is administered, or who gets it, is beyond the limits of science and enters the area of politics." The scientist, in question, explains that he is not a politician, and therefore his responsibilities do not extend beyond making sure that the drug is medically safe. Do you agree with this view?

- this question should serve as a springboard to the following questions concerning:

(a) the limits of science
(b) the neutrality of science
(c) the social responsibilities of a scientist (bioethics)

4. A scientist suggests that science is neutral. Do you agree?

- concept that science itself does not perscribe answers to ethical decisions, but in deciding whether or not to do science,or approach a problem from a scientific paradigm, we demonstrate a non neutral position.

5. During the forum, medical (humanitarian) reasons were given for using research money and facilities to discover a drug that would reduce the aging process (eg. Alzheimer's disease or the rare aging abnormality -- 8 year old boy shown on "That's Incredible"). However social, economic and religious reasons were given that opposed the research.

a) How is it possible that medical science provides us with reason to do the research while economic reasons oppose the research?

- Note - not all scientific reasons indicated that the research should be done, nor did all economic reasons oppose the research.

- this question may provide some information about different world views.

- the same question persued from divergent "paradigms" with different ways of formulating, and organizing kowledge.

b) Did both arguments present good points?

c) Is one method correct and the other incorrect, or are they both correct? (when we operate from within the boundaries of that perspective).

- these questions (b & c) are formulated around the notion of an "absolute truth".

- is correct consistent with the perspective in which it was developed.

- easily related to Rollo May essay (Capra-relativity as a curriculum plan.

6. Is it possible that one scientist could indicate that we should do the research while another suggests that it should not be done?

- addresses the interactive nature of science and society.

- re-examines many of the concepts present in question #1.

- scientists are more than science doers -- they bring a personal and cultural knowledge (Polanyi) background to their research.

(use example from forum - eg. living longer but with cancer, heart disease etc.)

a) How do we know which one to believe?

- underlying questions

(a) do scientists decide for us?

(b) does scientific reasoning tell us which path to follow?
(c) what are the limits of science in deciding what must be done?

7. In doing research on the aging process a scientist is asked to consider only the science of the question concerning aging. He or she is asked to remove himself or herself from the social, economic or political factors in order to remain objective about the research.

a) Do you agree with this advice? Explain.

b) Can it be done?

8. What if a scientist suggests that it is advantageous to do research, while a sociologist suggests that it would be disasterous. Which one would you believe?

9. A proponent of the research suggests that if science is smart enough to stop the aging process it could also control overpopulation, food shortages and other consequences of increasing the age span. Do you agree?

Possibility for follow-up - also qualitatively use TOURS (eg) #60 - only selected questions.

10. Why do you think more money is spent in trying to find a cure for cancer than trying to control malaria and human liver flukes (parasites), which kill more people each year than cancer?

- check for #2

APPENDIX B

RECOMBINANT DNA - INTERVIEW QUESTIONS

1. In one part of the debate a student indicated that we must trust science and scientists.

(a) Why do you think the student gave that response? (eg. how did they arrive at that point of view?)

Reason for asking the question:

- Are students aware of divergent perspectives?
- Do they recognize that personal knowledge, individual values (etc. - Polanyi) affect what appears to be only a scientific decision?
- Can divergent perspectives be accepted and/or appreciated?

(b) Are the terms science and scientists the same? (Refer to students statement)

This question may provide some insight into the way in which they (students) view science. (eg) mechanistic or humanistic activity. (eg) - science as an activity

Is the scientist only the doer of the activity or is (he or she) also perceived as a man, with individual qualities that affect his way of doing science, seeing the world?

2. If a person objects to research on Recombinant DNA and aging, would you classify this person's attitude as "anti-scientific"? Why or why not?

- Do they appreciate divergent opinions?
- Is science an "all or none" activity. (eg) do we totally accept it or reject it?
- Can a person who likes school science reject some of its endeavors?
- Were the objectives to Recombinant DNA research raised by people who do not like school science?

3. If a person supports Recombinant DNA experiments, does this make them "Pro Science"? Why or why not?

- Many of the same points as question #2, but stated from the opposite perspective.

4. Do you think that it is possible to support the Recombinant DNA scientists and yet oppose those who wish to interfer with the aging process? Why or why not?

- Many students did support one form of research, but opposed the other.
- Are people consistently pro or anti science and technology?
- Is their attitude towards science and research inextricably tied with the social context in which science is developed?
- The initial research indicates that students are consistently "Pro" or "Anti" science - if they do well in classroom science.

5. Which person, the one who supports the research on Recombinant DNA or the one who opposes it, would be held in greatest esteem by the public? Give your reasons.

Public perceptions of science - relate to Handler's essay on the Publics Opinion of Science.

- This question can very easily be related to question #6, which looks at their perceptions of the scientist.
- Do they feel that society trusts scientists?
- Are scientists well respected by the general public?
- This can be related to questions #1 and #2 on aging - regarding the social interactions of science and technology.

6. What do you think the Recombinant DNA scientist would look

like? (give reasons) (eg) old - young, glasses - no glasses, bold - shy, dress (etc.)

- Do the students provide the stereotypic image of the scientist as portrayed on TV?
- Is their view of the scientist influenced by their discussion?
- Much of the early research indicates that students arrive at a conception of the scientist early, and that these images are stereotypic, long enduring and generally formulated independent of the classroom context. (I do not believe this to be true).

7. Do you think that your parents would hold you in higher regard if you supported scientists, such as the researchers in Recombinant DNA, or if you oppose them?

- Public perception of science.
- Is there an age difference in the manner in which they feel that people view technological and scientific?
- What are the public and parental demands upon them? (To conform or question)
- An important relationship to question #5 and possibly #2 and #3.

8. Did you feel that one side of the discussion dominated? If so, why?

- Are they dogmatic in the beliefs?
- Is there tolerance for other points of view?
- Did they gain an appreciation for why different students hold different world views?

9. Did you find yourself changing your view or modifying your position either throughout the debate, or while writing the paper? Why?

Direct application of question 8

10. During the debate it was suggested that Nuclear Fission experiments lead to the atomic bomb, and that Recombinant DNA will lead to biological warfare.

- The opposing side indicated that nuclear weapons have not been used, and in fact may act as a deterent. They go on to argue that biological warfare will also not be used.

- Why do you think that both sides hold such divergent perspectives?
- Do they understand the rationale for divergent views?

- Relate to question #6 on Aging (divergent world views)

- Is it "science view" versus "anti-science view", or is the perspective developed within the confined of the social issue?

11. Is the decision whether or not to do the research a scientific decision?

- Students perception of the limits of science.

APPENDIX C

EXCERPT FROM ONE INTERVIEW TRANSCRIPT OF BETA GROUP

The interview was held on March 22, 1984, involving a group of four students; B, K, L and C from the beta group and myself. The interview followed the Aging Debate-forum which occurred on March 8, 1984. The questions asked in the interview were constructed after the debate, and appear in Appendix A, along with my rationale for asking the questions. The 50 minute interview produced a lengthy transcript. Therefore, an excerpt taken from this interview is presented below. It will indicate to the reader the manner in which the interview was organized and conducted.

I will provide a series of dots (...) to indicate a pause. No attempt however will be made to interpret voice inflections or non/verbal communication within the transcription of the interview.

All four interviewees participated in the Aging Debate.

Interviewer

> What I am going to do is ask you questions about science and scientists. The purpose of the interview is not to re-examine what you said during the debate, nor is it to defend what you said during the debate. So despite the fact that two of you supported the research into the aging drug and two of you opposed it, don't let that influence what you are going to say right now. I'm not looking at which side was right and which side was wrong. So don't agree with someone just because you agreed with them during the debate.

Can science through technology affect society?

C Very much so.

Interviewer

How C?

C Because everything we do like through medicine, affects the way we live. Science affects the way we live.

Interviewer

Does that apply to aging drugs?

C We could change the population growth or the death rate.

L Yah, science is always changing society. Every drug changes society.

K All science changes society, like computers are changing industry.

Interviewer

B, what do you think?

B Yes, the same thing. Well, it makes everything better. The population grows and expands, and that makes more jobs.

Interviewer

Do you think that science research could affect the family? The way your brothers and sisters relate to each other, you know the whole family unit?

C Well, say that your brother has got cancer. Science might find a cure. That's going to affect you.

L With the Aging Drug, lets say that your grandmother is old and that. But if you had this drug, then no one would really be old, but it depends what they would do with it...

Interviewer

One of the guys in the other class said something like that. He said what happens when old people aren't really old?

Lets try the second question. Can this new type of society, that has been changed by this research - say the Aging Drug, alter the type of research that's done in

the future?

C There's going to be more research done on the old. Say better medicines for old people, more research in arthritis, and other diseases that affect old people. The people that fund research, will know that there are more old people, so they will put more money in that area. ...

L Well, if we keep getting new technology then different things will be needed. Like arthritis may not be around, or any disease. Then new diseases might be coming around, things like radiation. These new diseases can be caused by technology.

K Thats right.

Interviewer

Do you think this older population would still be interested in space and some of the other things that we are interested in today?

L Yes.

K Definitely.

B Actually the scientists, doing space research would live longer, so there would be even more research.

Interviewer

A scientist suggests that his function in society is to find a drug that slows the aging process. This is what the scientist says: "how that drug is administered, or who gets it is beyong the limits of science and enters the area of politics". The scientist in question explains that he is not a politician, and therefore his responsibilities do not extend beyond making sure that the drug is medically safe. Do you agree with this view?

C I think he is really wrong. You can't create something and then say that it is their responsibility (politicians) to deal with it. He is the one who made it. He should realize the power that he has in

his hands and in his mind. You can't just dump the problem on someone else, and say, I made it, now you guys deal with it.

L Yeah, he has a moral responsibility.

Interviewer

But what if he says, look I made the drug and I know that its safe, but I can't control society. I don't know what its going to be like in the future, that's up to politicians. That's a decision that I don't even have to concern myself about.

K Well, I think that maybe, we could make the drug, you should talk it over with politicians and then see what they would do with it. Then let the politicians take over.

C But you can't.

K They would hold control eventually.

L Maybe though they could get a plan. Maybe they could have a waiting period to discuss how it would be used.

B But that wouldn't work because the Aging Drug would be in such great demand. Just one wrong person gets the drugs and that's it. No matter the research scientists really can't control it.

Interviewer

You see what raises the question is that many scientists who did research in nuclear fission, and from this research, done in part by pacifists like Neils Bohr, came the A bomb. And the scientists were saying that it was not their responsibility. What do you think? Was it their responsibility?

C Well, on T.V. they interviewed the scientists who invented the bomb and I think that about four out of five indicated that they wished that the bomb had never been invented. You give man the powerful weapon, and when it gets into world politics, the world as a whole is

not at peace. You can't give one side a big advantage like that. Maybe when the world is at peace in about 200 years, then maybe you could do the research.

B But there would be no reason to do research on the bomb then. It should have never been invented. It if gets into the wrong hands or is misused, then people will say that it should have never been invented.

Interviewer

A scientist says that science is neutral. It is not good it is not bad, it's experiments. There are no values in science, just a search for truth in nature. Do you agree?

C You can't say that building a bomb is just an experiment. Once you build it someone is going to use it.

K That's right, science is done for a reason.

Interviewer

Well, how about with the Aging experiment. The scientist might say that he is using standard lab procedures. The microscope is not good or bad. I'm using standard scientific methodology. Do you agree with him or disagree with him?

K But it is not neutral. You could be in there (lab) everyday and come up with something that you didn't intend.

B Or someone might use your work in a different way.

L There are no guarantees.

Interviewer

During the forum, medical (humanitarian) reasons were given for using research money and facilities to discover a drug that would reduce the aging process. Remember that rare aging abnormality that was discussed during the debate, where the

8 year old boy was dying of old age. However social economic and religious reasons were given for opposing the research. How is it possible that medical science provides us with reasons to do the research, while religious and socially based reasons oppose the research? pause...

C You're looking at it from two different viewpoints. There are two different sides of society. One wants to help these people who are suffering, but the other side of the argument is concerned with what will happen to society; like overpopulation and those kind of things. They have different viewpoints.

K Yeah, they just look at the problem differently.

Interviewer

If a sociologist looks at a whole group of people, and the medical person looks at one individual, can they come to different conclusions?

C No, not if they are both intelligent and consider it from both views.

L But what if the sociologists know someone suffering from Alzheimer's disease?

Interviewer

Did both arguments present good points?

B Yes, I found myself agreeing with some of the points from the other side during the debate.

K Me too... Lots of good points were raised by both sides.

Interviewer

Is one method correct and the other incorrect, or are they both correct? Can we use both viewpoints? For example if you focus on the individual, you might come to the conclusion that the research is good, however many who focused on the

society indicated that the research should not be done.

K No - both views are correct.

L No - one view is not right.

C I agree.

B If you know the eight year old boy then that's your viewpoint. It would be hard to look at the whole of society and forget him.

C But you must look beyond the individual, and consider society as a whole and look at generations from now. We have a responsibility beyond the individual.

K All the views were very important. If you put them altogether then they made sense. Like both views were right.

Interviewer

But how about people who suggest that what's right is right. It doesn't matter which starting point you begin from, if it gives you the right answer it's true. The starting point will not affect your answer.

K There is no absolute right. You can't look at this eight year old boy and say that he can't have the drug for the good of society. If you have any human feelings you can't say - you can't have the drug. But if you do - then you have overpopulation. It's hard to say anything is absolutely right.

L If you take an issue like this, what is good for the individual is not always good for society. There is no real answer, all that we have is a viewpoint. One looks at the individual, the other looks at society.

Interviewer

Is it possible that one scientist could indicate that we should do the research while another suggests that it should not

be done?

K That's possible, ... like they could argue, why or why not.

B Oh yes, they may look at different aspects. They have personal feelings. One could be looking at just the little boy, while the other may be looking at a perfect generation. You know everyone stays a certain age, and they are so well fit; while the other might feel that you could prolong the life of somebody that's already sick, you know. They could just have different points of view, and it could be possible.

L I was just thinking that if scientists were just thinking of the individual they may be arguing just over whether or not it could be possible.

C Scientists can have different opinions. They are people just like you and me. Everyone has different opinions about different things, and they can look from different viewpoints about how it affects society.

Interviewer

B, you said that scientists bring certain feeling and opinions into their experiments. Do you agree with that?

L Oh yeah.

K Like a scientist may say yes I'll do it because it's good, but others would do it just for the money. Different people respond in different ways.

Interviewer

You have indicated that scientists want the research on aging drugs present good arguments, while those who oppose the aging drugs also present good arguments. How do we know which one to believe?

C You have to look at both points of view, and then do what seems realistic to you.

B You have to look at which is more important to you; curing that child or getting a select group in society, or changing all of society and maybe getting chaos. Whichever you think would be best. Whether you cure those people suffering from the aging disease, or the drug could get out on the streets and change society. It's up to you. If you feel that the drug can be continued or not.

Interviewer

Suppose that two scientists come in and give opposite arguments. And a person evaluating the arguments says that they will make their decision based on which scientist is smarter. Do you agree with that reason?

L One may have more scientific knowledge, and if he has more and better arguments that good. But you also have values and the scientists values should be the same as your values. That's the one you go with.

K That's right. Just because someone is a scientist doesn't mean that they're smart about everything.

Interviewer

In doing research on aging a scientist is asked to consider only the science of the questions concerning aging. He or she is asked to remove himself or herself from the social, economic or political factors in order to remain objective about the research. Do you agree with this advice?

C No - definitely not.

K It can't be done.

Interviewer

Can it be done?

C You would have to live in a box all of your life. How could you do it? Like if someone is doing research on cancer are you going to say; don't think about your

mother who is dying of cancer. People are going to work harder when they really want it to work, (find a cure).

Interviewer

But if a scientist doesn't remove himself from society how can he be objective. Is it better that he removes those influences?

K No, he's got to know what's happening. He has to know about society, and why they need the drug, and how they will use it. If they remove themselves from society, they could remove themselves from the law. Scientists could be doing things that are illegal.

B No, no matter what you're doing you must consider how it will affect society. Take the A bomb for example, now they say that they wish that they had never invented it. Now, if they would have thought about all those people in Hiroshima, they would have never done it. Now the same thing could happen with the aging drug if they don't consider how it could affect society. It could end up harming more people then it is helping. The point is that you must consider how it is affecting society. Society is the people using it.

C You can have a bunch of scientists running around...scientist have a responsibility to society...

Interviewer

A proponent of the research (that's somebody who supports it) suggests that if science is smart enought to stop the aging process it could also control overpopulation, food shortages, and other consequences of increasing the age span. Do you agree?

C Scientists invented the birth control pill to control the birth rate, and they have decreased the death rate. But scientists can't as a whole, although they can help, change the world unless people --like countries of the world are behind them.

K Scientists can help us use things, but what happens if like all of the natural resources are used up. They can't make new resources. You can't make water or oil and food.

Interviewer

But they are coming up with alternate energy sources and new foods. So what if a scientist says, let us do the research because if we are smart enough to stop aging, surely we can find new foods. Have some faith in technology.

C They probably are smart enough. Technology is advanced enough, but the point is who is going to fund this.

K Is the new technology foods, like from garbage, is it really healthy? Sure it's a new food source, but is it any good? A powdered food that you only add H2O to; is it any good?

L The money spent on research comes from the rich. Maybe the aging drug would only benefit the rich.

Interviewer

Why do you think more money is spent in trying to find a cure for cancer than trying to control malaria or human liver flukes, which kill more people each year than cancer?

B Really?

Interviewer

Yes.

C ...probably because of the rich countries. Not too many people here in Canada suffer from liver flukes. The developed countries have the money to spend on research, but they spent it on the diseases that affect our people. The undeveloped countries don't have the money to spend on research.

L I'm not sure that this is right, but maybe

because in the future they think that cancer will be affecting more people.

B Maybe they want to catch it before it kills off lots of people.

C But liver flukes already kill more. How do we know it won't increase.

B I agree with C.

APPENDIX D

SEQUENCING OF QUESTIONS

A. Interrelationships Between Science, Technology and Society

Questions asked:

Aging: #1, #2, #3, #10

DNA: #1, #11

Sequencing of Interpretations

#1 (Aging Debate) Science -- Society

#2 (Aging) Society -- Science

#10 (Aging) Application, Society -- Science

#1 A trust in science (DNA)

#3 (Aging) Social responsibility of science/ limits of science

#11 (DNA) Limits of science

B. Image of the Scientist:

Questions asked:

Aging Debate: #6, #9

Recombinant DNA: #1, #3, #4, #6, #7

Sequencing of the Interpretations

#3 (Recombinant DNA Debate) Physical appearance of the scientist-stereotypic image?

#6 (Aging Debate) Can scientists disagree?

#3, #4 (Recombinant DNA) are people that support science, pro science, while those who oppose it, anti science? Attitudes towards science. - are scientists likely to agree with other scientists?

#9 (Aging Debate) - Faith in science

#7 (Recombinant DNA) - Prestige of the scientist

#8 (Aging) Do scientific answers dominate those of the social scientist or humanist?